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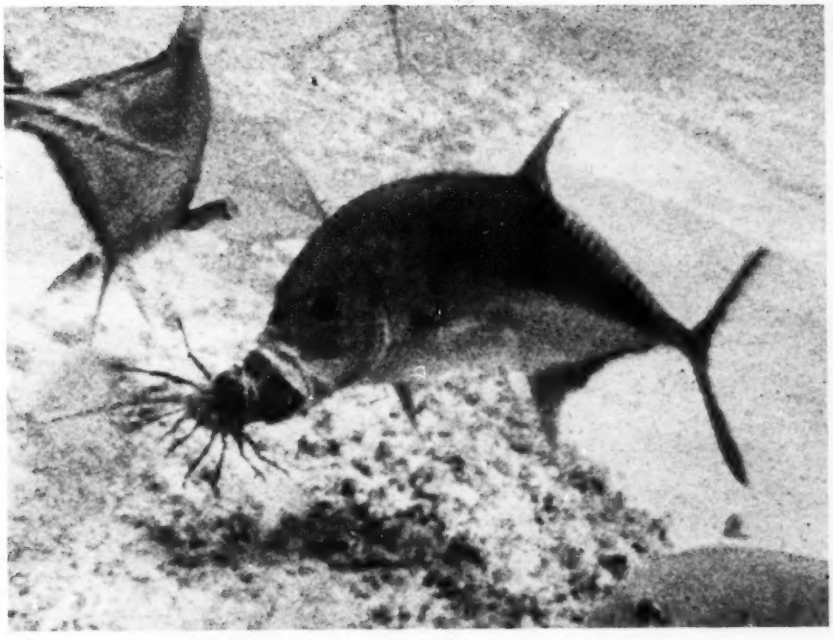

Spiny Lobster Predation

Marine Fisheries REVIEW

On the cover:
Predation on the spiny lobster is discussed in the article beginning on page 27.

U.S. DEPARTMENT OF COMMERCE

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A Genetic Method of Stock Identification in Mixed Populations of Pacific Salmon, *Oncorhynchus* spp.

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ABSTRACT—Basic procedures are presented and illustrated for a genetic stock identification (GSI) method that is based on the detection of genetic variability with gel electrophoresis. The method uses naturally occurring genetic differences between stocks to provide estimates of the composition of mixed-stock fisheries.

Three examples are given to illustrate the application of the GSI method to management of chinook salmon, Oncorhynchus tshawytscha, *fisheries: 1) Estimates for four potentially contributing populations of fall-run fish intercepted at Bonneville Dam (Columbia River) in 1980 and 1981, 2) an analysis of the 1982 winter gillnet fishery in the lower Columbia River, and 3) an analysis of the ocean troll fishery along the Washington coast during May 1982. The analytical, economic, and temporal advantages of the GSI method indicate that this procedure is a major new tool for the management of mixed stocks of anadromous salmonids.*

Introduction

A fundamental principle of fishery management is that knowledge of stock composition is required for effective management of mixed stock fisheries (Larkin, 1981). Absence of this knowledge inevitably results in either overharvest or overescapement. However, such a stock-composition strategy has been practiced rarely in the management of anadromous salmonids because of the difficulty in adequately identifying component stock groups.

Coded wire tagging (CWT) has given managers a valuable tool for identifying specific salmonid groups of hatchery origin, but the method is difficult to use on wild populations and requires considerable effort and cost (Ihssen et al., 1981). Scale analyses have been effectively applied to salmon fisheries (Messinger and Bilton, 1974), but their utility appears to be limited. Also, scale pattern standards can fluctuate between years with changes in environmental conditions, requiring yearly examination and revision of the standards.

An ideal set of stock discriminators should be: 1) Expressed independently of environmental changes, 2) composed of discrete units of information so that population differences can be readily quantified, 3) stable from year to year, and 4) measureable with reasonable efforts and costs. Protein differences detected by gel electrophoresis generally fulfill these requirements. These genetic differences readily accumulate among anadromous salmonid stocks because of the temporal and geographic reproductive isolation associated with the strong homing tendencies of adult salmonids.

The use of genetic data in the management of mixed stock fisheries of anadromous salmonids has been anticipated for over 30 years; for early reviews see Ridgway (1957) and Ridgway and Klontz (1960). Early development of the concept came from anthropologists who used the distribution of blood groups to trace patterns of human migration and to identify relationships among major population groups (Mourant, 1954). These studies, coupled with the successful application of blood grouping methods to genetically characterize populations in other mammalian and avian species (Stormont et al., 1951; Briles et al., 1950), suggested that serological procedures might also be extended to characterize breeding units of fish species. However, this idea was abandoned because technical problems limited its application (Hodgins, 1972). Protein gel electrophoresis ultimately provided the quality and quantity of genetic data that had originally been expected from blood groups (Utter et al., 1974); among existing stock identifying procedures, electrophoresis most closely approaches the criteria listed above for distinguishing differences among populations (Utter, 1981).

In addition to a reliable means for obtaining adequate volumes of genetic data, statistical and data processing methods were also needed to obtain estimates of stock contributions of mixed populations. A genetic stock identification (GSI) method has recently been developed and tested that meets these needs (Grant et al., 1980; Milner and Teel[1], and Milner et al.[2])

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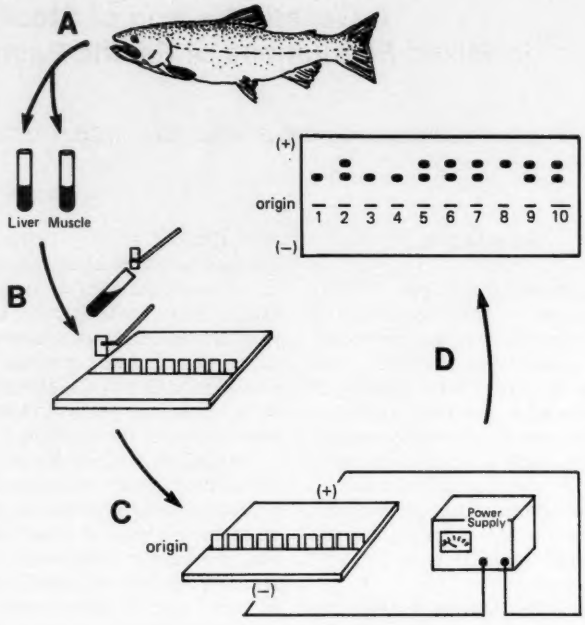
[1]Milner, G. B., and D. J. Teel. 1979. Columbia River stock identification study. Unpubl. manuscr., 68 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Prepared for U.S. Fish and Wildlife Service under Contract 14-16-0001-6438.)

[2]Milner, G. B., D. J. Teel, F. M. Utter, and C. L. Burley. 1981. Columbia River stock identification study: Validation of genetic method. Unpubl. manuscr., 51 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Prepared for Bonneville Power Administration under Contract DE-A179-80BP18488.)

Box A.—Basic Electrophoretic and Laboratory Procedures.

A. Tissue samples (e.g., muscle, heart, liver, and eye) are taken from each fish and placed in a culture tube with a small amount of water. Cellular proteins in the tissue are released into solution by freeze/thaw and mechanical agitation procedures.
B. A protein extract from each fish is individually absorbed onto a filter paper wick and placed onto the edge of a starch gel at the origin. Samples from 10 fish are shown loaded in the diagram, although typically, samples from 50 fish are loaded on one gel (i.e., with 50 wicks).
C. A direct current is applied across the gel. Protein molecules absorbed on each wick enter and move through the gel because of the molecule's net electrical charge and at a rate proportional to this charge. This charge, in turn, depends on the genetically controlled amino acid substructure of the protein molecules.
D. After about 4 hours, the gel is removed from the power source and the positions of specific proteins (usually enzymes) in the gel are identified by specific histochemical staining procedures (i.e., using general staining reagents or specific procedures involving the enzyme in the staining process). The relative migration distances of the proteins from the origin, indicated by the staining zones, are recorded as the raw data. The simplified genetic model used for interpreting electrophoretic protein variation is that one gene codes for one protein (polypeptide) chain. Therefore, electrophoretic differences between individuals in protein patterns that are based on amino acid differences are a direct reflection of genetic differences between the individuals. The simple extension of genetic differences between individuals to the evaulation of genetic differences between populations is outlined in Box B.



Steps for obtaining electrophoretic data.

It is evident from our early work that two conditions must be met for a GSI application. First, each stock that could contribute to a particular fishery must be electrophoretically characterized. Second, sufficient differerences among these profiles must be identified to permit measurement of contributions from each contributing stock.

An extensive data base now exists for chinook salmon, *Oncorhynchus tshawytscha,* populations ranging from California through northern British Columbia (Milner et al.[3]). This data base is centered on populations of the Columbia River whose stocks continue to be major contributors to oceanic fisheries from Alaska southward. Proper management of chinook salmon harvests in this area constitutes a major challenge to regulatory agencies (Van Hyning, 1973).

This paper outlines the basic procedures for applying the GSI and describes the use of the chinook salmon data base in the analysis of stock contributions to three chinook salmon fisheries of varying complexity. Its purposes are to illustrate the various steps of this procedure and to demonstrate its unique capabilities through actual management applications. The format is intended to provide a complete overview within the main body of the paper. The underlying principles of genetics, statistics, and data processing involved in applying the GSI are given in Boxes A and B.

Methods

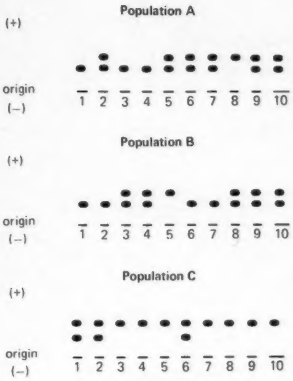
Use of the GSI method to estimate the composition of a mixed fishery can be divided into four steps.

Step I—Develop Electrophoretic and Laboratory Procedures

Initial laboratory work focuses on developing electrophoretic procedures

[3]Milner, G. B., D. J. Teel, and F. M. Utter. 1983. Genetic stock identification study. Unpubl. manuscr., 65 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Prepared for Bonneville Power Administration under Contract DE-A179-82BP28044M001.)

Box B.—The Use of Electrophoretic Data in Applying the GSI Method.



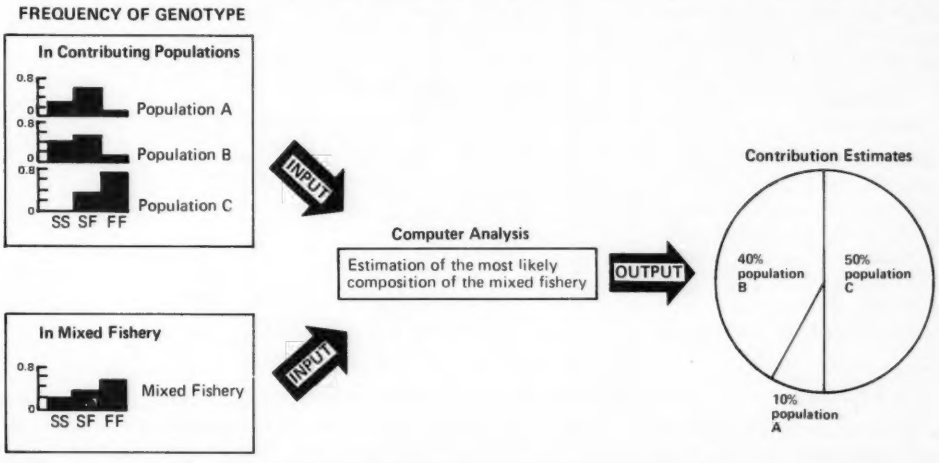
	Genotype frequency SS	SF	FF
Population A	3/10	6/10	1/10
Population B	4/10	5/10	1/10
Population C	0	3/10	7/10

Data from three gels are illustrated here to demonstrate general electrophoretic results and the classification of genotypes. Each gel contains a sample of 10 fish from one of three populations—A, B, or C. The samples are loaded at the origin and subjected to electrophoresis as outlined in Box A. The position of the enzymatic protein phosphoglucomutase (PGM) is made visible by a histochemical staining procedure specific for PGM. Each of the 10 fish in population A expresses one or both of the mobility forms of the protein PGM: A slow migrating form, S, and a fast migrating form, F.

These different electrophoretic expressions are direct reflections of the alleles (alternate forms of a gene) that direct the making of PGM. Fishes 1, 3, and 4 each have a single slow band in Population A. These fish received the same alleles from both parents for the manufacture of the PGM protein and are referred to as SS homozygotes. An SS homozygous individual, therefore, has two doses or copies of the S allele. Fish 8 has a single fast band and is an FF homozygote. Two bands are seen in six individuals of Population A. An individual with a double band has received dissimilar PGM alleles from its parents—here, an S allele from one parent and an F allele from the other—and is referred to as an SF heterozygote. The combination of alleles, e.g., SS, FF, or SF, that an individual possesses is referred to as its genotype. Genotypic frequencies are simply the proportions of homoyzgous and heterozygous genotypes for each protein system that is examined.

We have illustrated electrophoretic patterns for a protein that is functional as a single protein chain (i.e., a monomer). Although more complex staining patterns (i.e., phenotypes) can be seen for proteins functional as two or more protein chains, the genetic interpretation for variations of such proteins is parallel to that of monomeric proteins (Allendorf and Utter, 1979); single or multiple banded patterns are expressed by homozygous or heterozygous genotypes, respectively. We have also presented only two alternate alleles for the PGM protein system (S and F). Many protein systems have several allelic forms which increases their contribution to stock discrimination in GSI.

Genotypic frequencies are the fundamental sets of data that are needed to genetically characterize populations and to apply the GSI method. In the figure below, the genotypic proportions of all individuals sampled from a mixed fishery and those of three potentially contributing populations are jointly examined by a maximum likelihood procedure (outlined in Milner et al., footnote 3) to obtain estimates of the proportion of fish from each potentially contributing stock in the mixture.



Schematic of the GSI method using one variable protein system. In actual application, the power to discriminate between stocks and to estimate their contributions is increased by using the genetic variation found in many protein systems.

to detect genetic variation in as many proteins as possible. This phase involves a process of screening a large number of eletrophoretic recipes suitable for use with the species of interest (in this case, chinook salmon). Basic laboratory procedures are summarized in Box A.

Step II—Collect Baseline Data

The purpose of this step is to characterize genetically the major stocks which may comprise the mixed fishery. Baseline sampling occurs on individual stocks in freshwater habitats. Tissues from 50-100 fish per locale are collected. Genetic data are

obtained for the protein systems identified in Step I; the frequencies of the different genetic variants for each protein system are tallied. Data are compared statistically to determine if significant differences exist among collections. Data from collections which are not significantly different are combined, and the resulting individual and combined data are used as the baseline for mixed fishery analysis.

Step III—Collect Mixed Stock Fishery Data

Fish taken from a mixed-stock fishery are screened for electrophoretic variability at the same set of protein systems included in Step II. The sample size required for reliable estimates of stock composition is an important but complicated variable to determine. Factors affecting the required sample size include the degree of genetic differences among baseline stocks, the actual or potential number of contributing stocks, and the detail of stock resolution required for management purposes.

Step IV—Estimate Stock Composition

The genetic profiles for the baseline stocks and the mixed fishery samples are used to produce statistical estimates of individual stock or stock group contributions to the fishery. Details of the statistical procedures and the associated validation studies are given by Milner et al. (footnotes 2 and 3).

Applications

Three applications of the GSI in analyzing population mixtures of chinook salmon are described in this section (sampling locations are presented in Figure 1). These descriptions, representing successively more complex situations, are provided as examples of diverse management uses of the GSI.

Upper Columbia River Egg Bank

Two morphological types of chinook salmon migrate past Bonneville Dam on the Columbia River during the fall: Tules and brights. Tules are dark, mature fish returning to hatcheries in the lower and midpor-

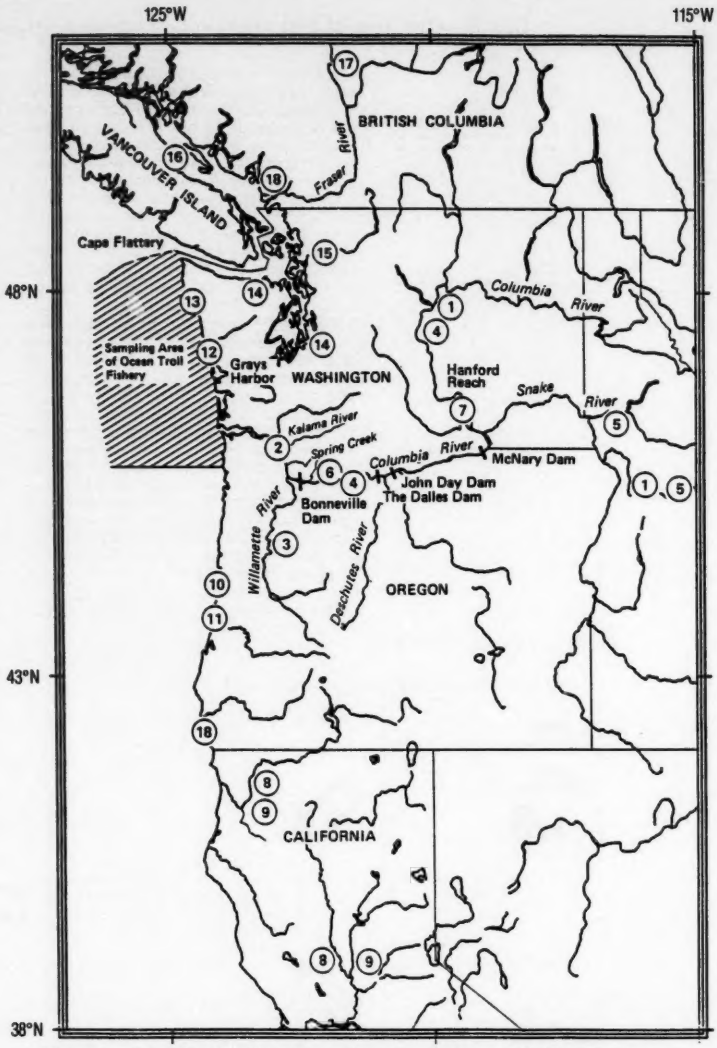


Figure 1.—Sampling locations for various seasonal runs of chinook salmon from California through British Columbia. Numbers indicate the 17 stock groups used in the data base for the analysis of the ocean troll fishery: 1) Upper Columbia River, summer-run; 2) Lower Columbia River (Cowlitz/Kalama), spring-run; 3) Lower Columbia River (Willamette), spring-run; 4) Upper Columbia River, spring-run; 5) Snake River, spring-run; 6) Lower Columbia River/Bonneville Pool, fall-run; 7) Upper Columbia River, fall-run; 8) California, fall-run; 9) California, spring-run; 10) Oregon coastal, fall-run; 11) Oregon coastal, spring-run; 12) Washington coastal, fall-run; 13) Washington coastal, spring/summer-run; 14) Puget Sound, fall-run; 15) Puget Sound, summer-run; 16) British Columbia, fall-run; and 17) Fraser River, summer-run.

tion of the Columbia River; brights are silvery fish, destined mainly for natural spawning grounds in the Hanford Reach area of the Columbia River. Smaller populations of bright fish spawn in the Snake River and in the Deschutes River (Pattillo and McIsaac, 1982). To increase the returns of the upriver bright portion of the Columbia River runs, eggs from fall-run chinook salmon at Bonneville Dam have been selectively used in an "egg-bank" program. GSI analyses of the egg bank interceptions were needed to estimate the relative proportions of the component populations to assure predominance of the Hanford Reach component and to minimize the impact on the drastically depleted Snake River run (Utter et al.[4]).

Genetic profiles were obtained for the three components of the bright stock and for tules from the Spring Creek National Fish Hatchery (NFH). Spring Creek NFH is not only the major contributor to the tule run, but, based on the genetic similarity among tule hatchery populations, is also genetically representative of other tule populations. GSI estimates of stock composition at Bonneville Dam were made for two consecutive years (Table 1). The data indicate a predominance of fish destined for the Hanford Reach area (79 and 86 percent) and much smaller contributions to each of the other three areas (2-8 percent). These estimates measure the impact of interceptions on the spawning populations involved and provide a better understanding of the genetic makeup of the resultant "egg bank" stocks.

Columbia River Winter Gillnet Fishery

A winter gillnet fishery occurs near the mouth of the Columbia River. This fishery is regulated by a variable—and usually brief—opening, because of the limited abundance of returning fish and concerns for adequate escapement to areas above Bonneville Dam to satisfy Indian treaty quotas (ODFW and WDF, 1981). A GSI analysis was conducted in cooperation with the Washington Department of Fisheries (WDF) and the Oregon Department of Fish and Wildlife (ODFW) in 1982 on this fishery to determine the proportions of fish returning to a number of areas downstream and upstream of Bonneville Dam.

Genetic estimates were obtained from a data base of 19 potentially contributing stocks and from over 1,000 individuals taken in the gillnet fishery. The estimates for five management units (Table 2) indicate that about 90 percent of this fishery was destined for terminal areas downstream from Bonneville Dam with populations from the Willamette River being the predominant contributors. These GSI estimates are similar to estimates obtained from coded wire tagging. For example, CWT information indicated 70, 5, and 10 percent of the fishery were destined for the Willamette River drainage, the Kalama River, and the cumulative upriver populations, respectively[5].

The two applications described to this point clearly demonstrate the value of applying the GSI to stock mixtures in the Columbia River. The existing data base is being directly applied to many other situations within the river as well, e.g., studying and managing the extensive lower river fishery for fall chinook salmon (chinook salmon are classified as spring-, summer-, and fall-run fish corresponding to discrete seasonal peaks in spawning migrations). It could also be useful in identifying origins of juvenile fish taken at various times and locations in their downstream migration.

Table 1.—Estimates of relative contributions (as percentages) of different stocks of fall-run chinook salmon intercepted for egg bank collections at Bonneville Dam in 1980 and 1981.

Baseline population	GSI estimates[1] 1980	1981	Run type
Spring Creek	7	2	Tule
Deschutes	6	5	Upriver bright
Hanford Reach	79	86	Upriver bright
Snake River	8	7	Upriver bright

[1] Genetic stock identification estimates based on 1,179 fish in 1980 and 475 fish in 1981, using 9 and 12 variable protein systems, respectively; approximate 95 percent confidence intervals for the estimates are less than 1 percent.

Table 2.—Estimated contributions by genetic stock identification method (GSI) of spring-run stock groups to 1982 winter gillnet fishery of chinook salmon in the lower Columbia River.

Stock group	Estimated contribution (%) (1 S.D.)
Below Bonneville Dam	
Willamette River	71.7 (0.1)
Other (Cowlitz-Kalama-Lewis)	17.2 (0.8)
Total	88.9 (0.1)
Above Bonneville Dam	
Between Bonneville and McNary	5.8 (0.6)
Above McNary (Columbia)	1.8 (0.3)
Above McNary (Snake)	3.5 (1.1)
Total	11.1 (1.4)

Oceanic Fisheries

The most comprehensive application of the GSI described in this article was a cooperative venture with WDF involving the May 1982 troll fishery off the Washington coast (for complete results see Miller et al., 1983, and Milner et al., footnote 3). The objectives of this study were to evaulate the GSI as a practical tool for management of oceanic salmon fisheries and to increase the information base for management of this fishery. The analysis included baseline data collected in the region from California through British Columbia, plus about 2,000 fish from the troll fishery (Fig. 1) proportionately sampled by area. The results for the overall fishery are presented in Figure 2. The lower Columbia River/Bonneville Pool fall chinook stock group predominated in the fishery over the

[4]Utter, F. M., W. J. Ebel, G. B. Milner, and D. J. Teel. 1982. Population structures of fall chinook salmon, *Oncorhynchus tshawytscha*, of the mid-Columbia and Snake Rivers. Processed Rep. 82-10, 14 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[5]D. McIsaac, Washington Department of Fisheries, Room 115, General Administration Bldg., Olympia, WA 98504, Pers. commun., 1983.

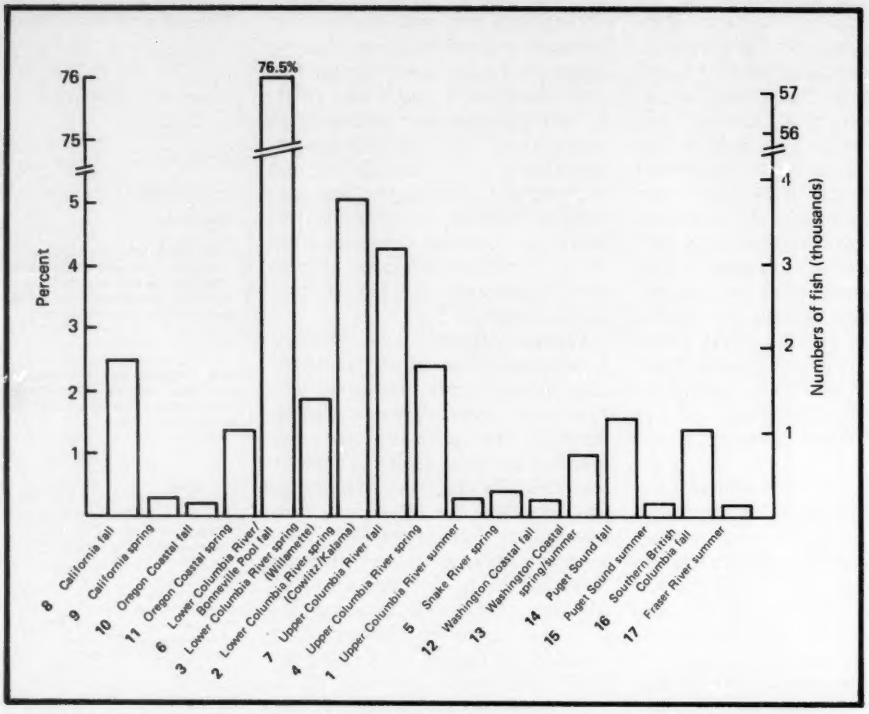


Figure 2.—Estimated proportions of contributing stock groups to the entire Washington ocean troll fishery, May 1982. Geographic locations are illustrated in Figure 1 (from Miller et al., 1983).

entire range. Heavy representation of this group in the harvest is desirable from a management perspective because of the predominance of flourishing stocks of hatchery fish.

As expected, the estimated stock contributions differed between fisheries in the Cape Flattery area in the north and the Columbia River-Grays Harbor area in the south (Fig. 3). For example, there was a higher representation of stocks from British Columbia, Puget Sound, and upper Columbia River fall chinook in the northern fishery. The lower Columbia River/Bonneville Pool group remained the predominant contributor to both areas. However, it represented a significantly lower percentage of the harvest in the northern area. A study of this detail had not previously been possible for an ocean fishery.

Potential for Extended Applications

These three uses of the GSI involving different segments of a common data base and distinct management applications indicate that this procedure has a huge potential for extended application. The method can be applied to any fishery when the following conditions are met: 1) A suitable number of genetic variants have been identified, 2) these variants are distributed among contributing populations at sufficiently different frequencies to permit estimating contributions with reasonable precision at practical sample sizes, and 3) the data base used to estimate contributions is representative of potentially contributing populations. These three conditions appear to have been satisfactorily met in the investigations of chinook salmon outlined in this paper. Migratory salmonids in general tend to meet the second condition; their strong homing instincts favor the formation of genetically discrete populations that can be identified by electrophoretic techniques. The observed stability of data bases among generations and over year classes (Utter et al., 1980) enhances the value of the GSI. Once adequate baseline data have been collected for a species in a particular area, the primary focus can be on mixed fishery analysis.

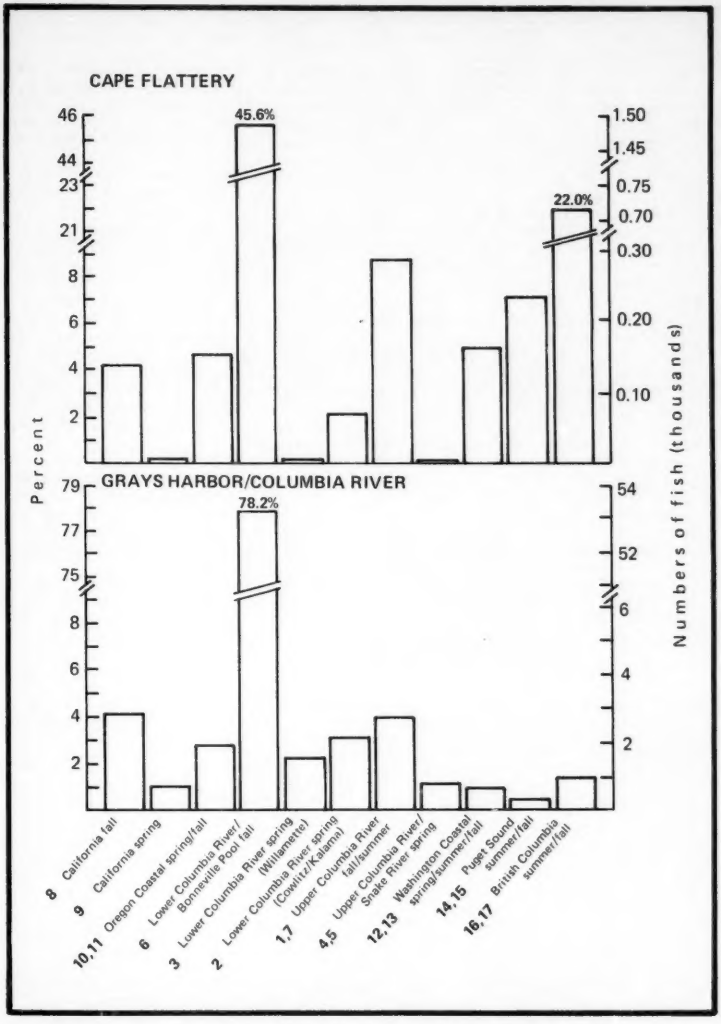


Figure 3.—Estimated proportions of contributing stock groups in northern and southern areas of the Washington ocean troll fishery, May 1982. Geographic locations are illustrated in Figure 1 (from Miller et al., 1983).

The cost advantage of the GSI approach over other procedures used to estimate stock composition is dramatic. The greatest expense in the GSI approach is the collection of the baseline data (i.e., Step II), but once an adequate data base has been collected, the primary focus can be on mixed fishery analysis. Thus, predominant costs for GSI applications are in the collection and analyses of mixed fisheries. A comparison of these costs with those of the CWT approach is necessarily indirect because of the exorbitant expense of tagging wild populations.

Costs for GSI estimates are at least an order of magnitude lower than those of CWT for similar information, even assuming that wild stocks could be tagged and that cost would be the same as that of hatchery tagging. We have conservatively estimated a total wild and hatchery chinook salmon smolt production from California northward through British Columbia of 251 million (Smith and Wahle, 1981; Perry[6]). About 10 percent of these fish would require tagging to achieve the same levels of precision in estimates as that attained by the GSI method in the 1982 May troll fishery (Milner et al., footnote 3; Ossiander[7]). The cost to apply CWT to fish in hatcheries is about $50/1,000 fish or $1.26 million for one year class and $3.78 million for three year classes—the amount required to effectively sample the fishery.

In contrast, contractual costs since 1976 for the development of the chinook salmon baseline data and the procedures for GSI estimation, and for the collections and analyses of the mixed fishery data (including those described above), total about $650,000. Now that a usable data base has been collected, subsequent costs for similar analyses within this region will be much lower.

The GSI is viewed as a complement to, rather than a replacement for, other procedures for identifying fish in population mixtures (Ihssen et al., 1981). Tagging and marking methods remain necessary for such applications as evaluating experiments and identifying migratory routes of individual fish. Uses of scale characteristics have proven, and will remain, valuable for many applications involving destinations and origins of population mixtures. However, the proven and comprehensive discriminatory powers of the GSI coupled with its potential for in-season management and reasonable costs have opened new horizons for

[6]T. Perry, Department of Fisheries and Oceans, 1090 W. Pender Street, Vancouver, B.C., Canada V6E 2T1. Pers. commun., 1983.
[7]F. Ossiander, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. Pers. commun., 1983.

the study and management of mixed stock fisheries. An accelerated use of the GSI therefore appears certain during the current decade as suitable data bases accumulate.

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An Ecosystem Model Evaluation: The Importance of Fish Food Habits Data

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An important aspect of model evaluation is validation—that is, the process of confirming that model behavior corresponds to reality. Model results can be validated by comparison with field data, but this technique limits the validation to a particular set of field conditions (Miller, 1974). A less restrictive method is sensitivity analysis: Model runs in which input parameters are perturbed one at a time and compared with a base model run using the best estimates of input parameters. This type of sensitivity analysis is called individual parameter perturbation (IPP). If the input parameters are perturbed by an amount equal to their range of error, the sensitivity analysis gives an indication of the amount of error in model outputs.

Sensitivity analysis also yields other information that can be of use to the modeler, some of which is suggested by Waide and Webster (1976). One use of sensitivity analysis is in resource management, where manageable parameters can be identified and their effect on the system can be evaluated. The analysis can also pinpoint those particular input parameters that cause the most change in model outputs, thereby directing research effort toward obtaining more precise estimates of these parameters (Wiens and Innis, 1974). The sensitivity analysis reported here was performed for such research effort allocation, to describe model behavior when input parameters are changed, and to identify parameters which are most important in determining model output values.

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ABSTRACT—Sensitivity analysis of an ecosystem model for the Gulf of Alaska revealed the importance of fish food composition parameters in determining model outputs. Since food habits parameters are important to most multispecies models which have predation as the main source of species interaction, the parameters should be estimated as accurately as possible. Unfortunately, collection of data on fish feeding habits in the North Pacific has been sporadic, and the estimation of model predation parameters from the data is thus subject to a great deal of error. The importance of developing a standardized data base on fish food habits is emphasized in conjunction with the use of the data base to improve ecosystem model reliability. A four-stage process is described for data base development and recommendations are made for future food habits research.

The Model

The Bulk Biomass Model (BBM), developed by Taivo Laevastu at the NMFS Northwest and Alaska Fisheries Center (NWAFC), Seattle, Wash., estimates the equilibrium biomasses of fish and invertebrate groups in a given marine region (Livingston, 1980). The region in this particular adaption of BBM is the Gulf of Alaska (Fig. 1). The region is divided into five geographical areas with three different habitats in each: Coastal, slope, and offshore. The model consists of a set of equations which describe the biomass of species or species groups of fish and invertebrates in terms of species-specific

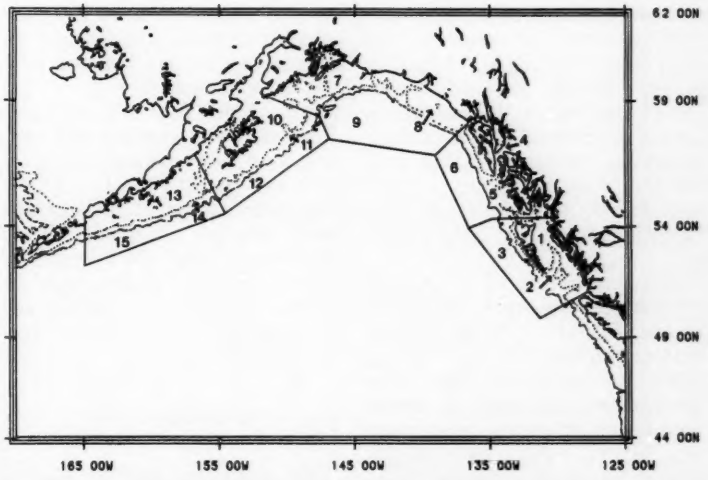

Figure 1.—The Gulf of Alaska region covered by the model and the location of computational subregions.

biomass growth (G_o) and removal (Fig. 2). There are four sources of removal input as constants or calculated in the model:

1) Predation by man through fishing (F);
2) Predation by birds and mammals ($M1$);
3) Predation by fish and invertebrates ($M2$); and
4) Old age and disease mortality ($M3$).

Fishing mortality (F) and old age and disease mortality ($M3$) are species specific constants. Bird and mammal predation ($M1$) is calculated in the model given:

1) Bird and mammal biomass (B_{mam});
2) the rate of bird and mammal food consumption (K_{mam}) in terms of percent body weight consumed per month; and
3) the fraction of each fish and invertebrate group in the diet of each bird and mammal group.

Predation of fish and invertebrates ($M2$), which provides the link between fish and invertebrate groups, is calculated in a manner similar to bird and mammal predation. Each fish and invertebrate group has given food requirements for growth and maintenance, K_g and K_m, defined in terms of percent body weight consumed per month. It also has a prescribed diet defined in terms of the proportion by weight of each prey fish and invertebrate group, i, in the total food for each predator fish and invertebrate group, j, designated as $\rho_{i,j}$.

A general set of $\rho_{i,j}$'s for each predator species group was first derived from a survey of the literature on the food habits of North Pacific fishes (Livingston and Goiney, 1984). Since the literature often does not contain information on spatial variations in fish feeding habits, each group's general diet was then modified, based on empirical knowledge of the distribution of prey species, to produce a different diet for each habitat: Coastal, slope, and offshore. Lastly, a biomass estimate was made for each group to calculate group food requirements.

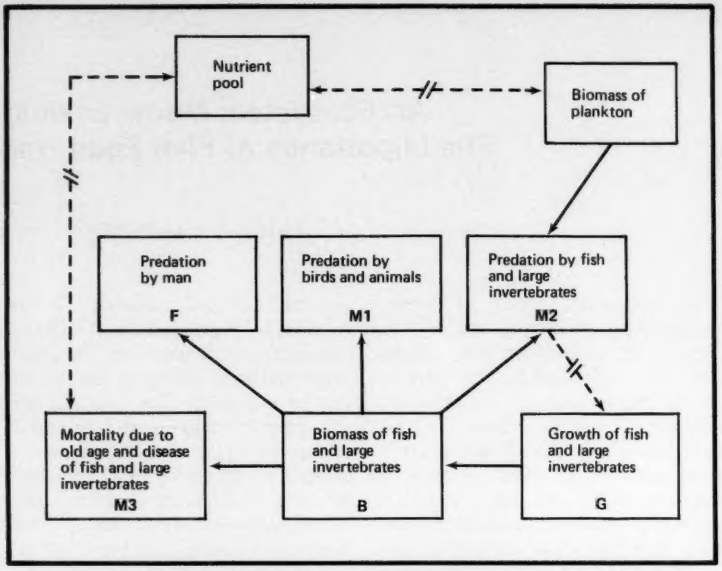

Figure 2.—Simplified view of biomass flow in the Bulk Biomass Model (dashed line = not modeled).

With the exception of some base groups whose biomasses are well known, the model estimates equilibrium biomass of each fish and invertebrate group. An initial guess of each group's biomass obtained from resource assessment data, $B_{i,j}$, is input into the model. Then an iterative procedure is used which continually readjusts these initial estimates, using the biomass growth and removal parameters discussed above, until each group's biomass is in equilibrium. Thus, the estimates of growth and removal parameters set up the determination of the fish and invertebrate group's equilibrium biomass level.

Sensitivity Analysis of the BBM

The sensitivity analysis requires estimates of the absolute standard error, E, in model input parameters G_o, ($F + M3$), K_g, and K_m, mammal and bird biomasses (B_{mam}), and the proportion of prey i in the diets of predators j ($\rho_{i,j}$). These figures were derived from a survey of the literature. Since it was not possible to assign a specific error to each $\rho_{i,j}$, the error was determined to be derived from the process of estimating a different diet for each subregion. A series of model runs was made in which each set of parameters was increased and then decreased by its estimated error (Table 1). Only one run (run 15) was made to test the effect of error in the food habits parameters $\rho_{i,j}$. For that run, each species' diet in each subregion was entered as the original literature-derived general diet for that species, which did not consider possible changes in prey availability in coastal, slope, and offshore subregion types.

For the remaining runs (1-14) the perturbed value, P'_i of a parameter P_i, is:

$$P'_i = P_i (1 \pm E')$$

where E' is the fractional error (E' =

Table 1.—BBM sensitivity model runs and parameter changes.

Run no.	Parameter		Parameter change
1	G_e	Monthly growth coefficients for each fish and invertebrate group	−10%
2	G_e		+10%
3	$(F + M3)$	Monthly fishing and natural mortality coefficients for each fish and invertebrate group	−15%
4	$(F + M3)$		+15%
5	K_g and K_m	Monthly food requirement for growth and maintenance for each fish and invertebrate group	−20%
6	K_g and K_m		+20%
7	B_{mm}	Biomasses of each bird and mammal group	−50%
8	B_{mm}		+50%
9	$B_{i,1}$	Initial biomasses for all fish and invertebrate groups	−50%
10	$B_{i,1}$		+50%
11	$B_{i,1}$	Initial biomasses for base fish and invertebrate groups only	−50%
12	$B_{i,1}$		+50%
13	$B_{i,1}$	Initial biomasses for all fish and invertebrate groups except base groups	−50%
14	$B_{i,1}$		+50%
15	$\rho_{i,j}$	Same fish and invertebrate food composition for all subregions	

E/P). This method of sensitivity analysis, called individual parameter perturbation (IPP), assumes that interaction effects among parameters are not significant. This may not be true for some complex models (Rose, 1981). In this study, fish and invertebrate equilibrium biomasses, B_i, and their annual mortality rates ($M1_i + M2_i$)/year due to predation were measured for sensitivity to parameter changes.

The sensitivity results can be expressed in terms of percent change of a dependent variable, X, from the base run, as suggested by Orth (1979). This sensitivity indicator, S'_i, is simply

$$S'_i = \frac{X_i - X_b}{X_b} \cdot 100$$

where X_i is the value of the dependent variable X when the ith parameter is perturbed and X_b is the value of X in the base run of the model which contains best estimates of all the parameters. Table 2 summarizes the range of these sensitivity coefficients, S'_i, over model subregions for all sensitivity runs, including the food composition run. Total equilibrium standing stock biomass (B_i) and mortality/year [$(M1_i + M2_i)$] in each subregion are the dependent variables. Food composition changes (run 15) not only produced the widest range of sensitivity values but also the highest values. Decrease of growth coefficients (run 1) and increase of food coefficients, K_g and K_m, (run 6) also showed high sensitivity values with some variation between subregions. The sensitivities from the other runs were not as high or as variable as runs 1, 6, and 15.

Table 2.—Range of percent change, S'_i, in dependent variables, B_i and $(M1_i + M2_i)$, over model subregions for sensitivity runs 1–15.

Run	Test	Range of S'_i			
		B_i		$(M1_i + M2_i)$	
1	$-G_e$	62.4,	83.7	35.1,	54.2
2	$+G_e$	−28.0,	−33.4	−15.5,	−22.4
3	$-(F + M3)$	−21.0,	−25.3	−12.9,	−17.2
4	$+(F + M3)$	34.2,	47.0	20.6,	31.2
5	$-K_g$, $-K_m$	−42.5,	−48.0	−40.1,	−47.1
6	$+K_g$, $+K_m$	71.6,	87.9	66.6,	84.8
7	$-B_{mm}$	−1.0,	−17.4	−1.0,	−17.9
8	$+B_{mm}$	1.0,	17.4	1.1,	17.9
9	− all $B_{i,1}$	−32.6,	−49.0	−32.1,	−48.9
10	+ all $B_{i,1}$	32.6,	49.0	32.1,	49.0
11	− base $B_{i,1}$	−31.9,	−48.7	−31.7,	−48.8
12	+ base $B_{i,1}$	31.9,	48.7	31.7,	48.8
13	$-B_{i,1}$ except base	−0.8,	−1.0	−0.1,	−0.6
14	$+B_{i,1}$ except base	0.2,	1.0	0.2,	0.6
15	$\rho_{i,j}$ same food composition for all subregions	0.0,	126.8	0.0,	122.5

Thus, the model proved most sensitive to changes in food composition, growth rates, and food coefficients. These three parameters, along with fishing and old age mortality, determine directly or indirectly how much food is eaten and of what kind. Changes in these parameters most affected the heavily preyed upon groups—benthos, crustaceans, and other pelagics. The relative amount of each group's equilibrium standing stock biomass in the model therefore depends primarily on the model definition of predation processes.

Implications of Sensitivity Results

The sensitivity of model results to the model's rigid definition of predation suggests that expressing predation merely in terms of fixed percentages by weight of each prey item in a predator's diet may not be the best method for modeling predation processes. Development of an alternate structure which allows for feedback between system components might increase model realism. In fact, Gardner et al. (1980) found that more complex and realistic feeding terms for predator populations resulted in smaller within-model variances for their predator population estimates. The development of a functional relationship between predator and prey, for instance size dependent feeding, would thus provide the model with a better feedback structure for defining changes in size (age) composition of fish stocks due to predation. Such size composition information is necessary for management purposes.

These results pinpoint two problems in developing multispecies models: 1) There is a lack of useful data on the feeding habits of the fishes being modeled and 2) the functional form of the feeding portion of some models may be too deterministic. It follows that there are also two solutions to these problems: 1) To improve the quantity and quality of diet information collected on fish in the North Pacific and 2) to utilize this data and specific experiments to formulate a more mechanistic description of prey selection by fishes. For example, the results of the present study spurred the development of a flexible, prey availability-dependent representation of feeding in the largest ecosystem model called DYNUMES (Laevastu and Larkins, 1981) at NWAFC. Implementation of both of these improvements would reduce the error in the model, both through more reliable input data and through better use of the data. Specifically, the data should

FOUR STAGE PROCESS IN PRODUCING A FISH FOOD HABITS DATA BASE

I Planning	II Field sampling	III Laboratory analysis	IV Data analysis
Identify: 1. Geographic area 2. Species to be sampled: a. major commercial species (fish eaters) b. noncommercial species (fish eaters) 3. Number of samples to be taken according to: a. subregions within sampling area b. species size groups c. time of year	Collect required number of stomachs and label and preserve individually Record: 1. Station data 2. Lengths and sex of fish sampled 3. Stomach type a. containing food b. empty c. regurgitated	Identify for each stomach: 1. Prey items to species level, if possible 2. Weights, numbers and lengths of prey items	1. Code, keypunch and edit predator-prey information from lab analysis and associate it with the station data 2. Run programs to summarize, compute statistics and produce graphic output of data

Figure 3.—Description of a four-step process in producing a data base for information on fish food habits.

be used to define not just what a fish will eat, because in many fishes this may be extremely variable, but, more importantly, it should be used to quantify why fish eat what they do. For instance, a predator may select certain prey because they are of the appropriate size; to quantify this kind of relationship, we need a data base which includes measurements of individual prey sizes.

The procedure for developing the data base should involve detailed organization in the following four areas (Fig. 3):

1) Planning, in terms of identifying the specific geographic areas, fish species, and number of stomach samples;

2) field sampling of stomachs;

3) laboratory analysis of stomach contents; and

4) data analysis.

The goal is to produce a data base on food habits of uniform quality and format which can be easily accessed and summarized by computer. It would then be available in a readily usable form to those who wish to parameterize ecosystem models or to those who need basic information on feeding habits of fishes. The data base would provide a strong link between basic research and the theoretical models which require research data. The utilization of such data in ecosystem models would provide a quantitative view of species interactions and enable us to make more informed decisions on multispecies management.

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The Role of Cetaceans in the Shelf-Edge Region of the Northeastern United States

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Introduction

Man has been, and continues to be, a part of the ecosystem along the outer margin of the outer continental shelf (OCS). With oil and gas exploration and development added to the present fishing and shipping activities, this role may be on the increase. After 3 years of field studies, the role of another group of apex predators, marine mammals, can be characterized. These findings have application to decisions about resource utilization, habitat use, and the impacts of offshore activities.

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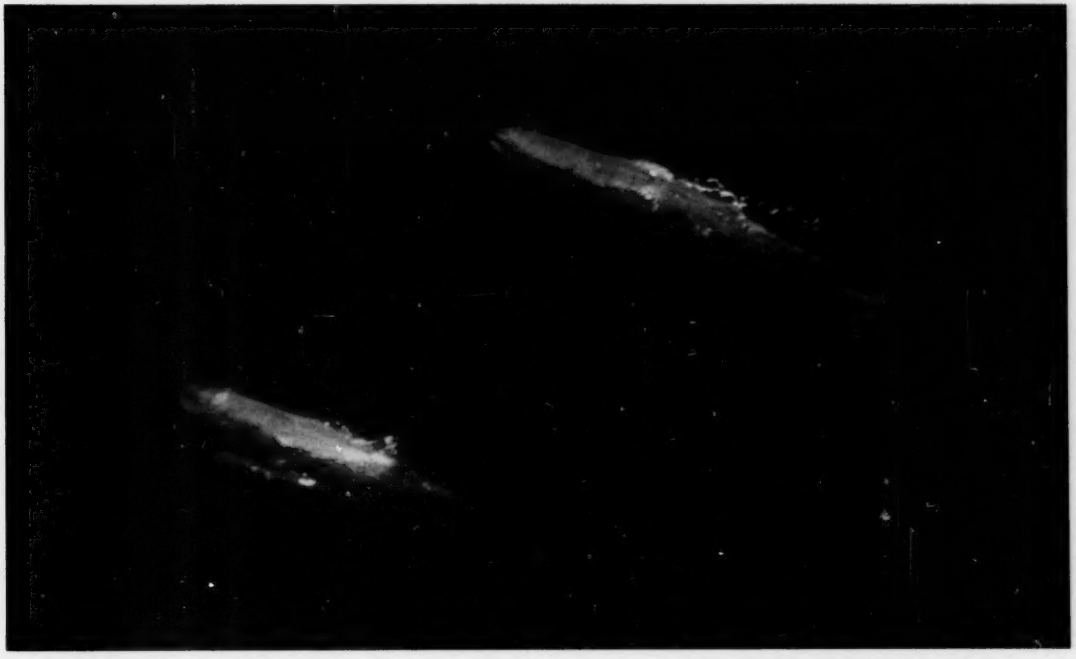
In this study, the shelf-edge region was defined as bounded by the 91 and 2,000 m depth contours, and by lines extending southeast from Cape Hatteras, N.C., and from the center of the Northeast Channel at the eastern tip of Georges Bank (Fig. 1). This region straddles the shelf break (200 m depth contour), is about 40 km (21.6 n.mi.) wide, and includes about 62,100 km² (18,100 n.mi.²).

This paper summarizes aspects of the findings from a large and multifaceted study. Details on sampling and data collection not included here are given in the final report of the Cetacean and Turtle Assessment Program (CETAP),



Three sperm whales (two adults and a calf) sighted by survey aircraft in deep water south of Georges Bank.

University of Rhode Island[1]. Additional findings on cetacean biomass and energetics in waters of the northeastern U.S. are reported in Scott et al. (1983). A review of morphology and energetics in relation to the food requirements of marine mammals is provided by Brodie (1984).

The principal findings reported here are:

1) Twenty species or species groups were reported in the region. Of these, 12 are common and 8 are uncommon or rare. Three species, the sperm whale, *Physeter catodon;* fin whale, *Balaenoptera physalus*; and pilot whales, *Globicephala* spp., together constitute >75 percent of the cetacean biomass.

2) During the season of peak abundance, spring, a minimum of 47,565 cetaceans may inhabit or transit the region. This represents a cumulative biomass of 26,506 metric tons (t).

3) The food requirement of the shelf-edge cetacean component is estimated to be between 64,000 and 960,000 t/year. The current best estimate within this range is 480,000 t/year. This value converts to a cetacean consumption of 9.7 Kcal/m²/year, which is in the same range as values reported for the highly productive Georges Bank region.

4) If our assessment is correct, then cetaceans must be considered a major component of the ecosystem. Their impact on resources of the region is substantial—perhaps equal to, or comparable to, that of man.

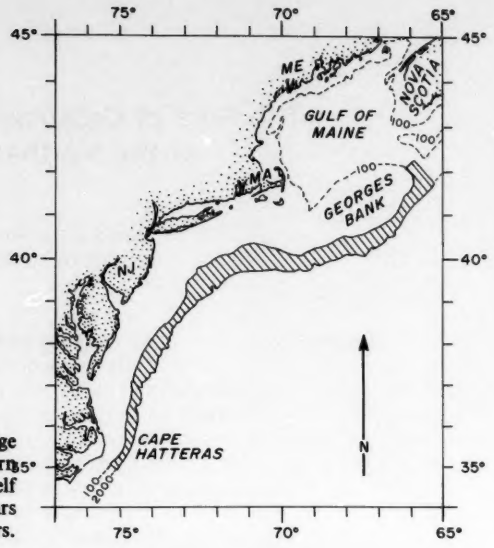


Figure 1.—The shelf-edge region of the northeastern U.S. outer continental shelf (lined area). Depth contours are labelled in meters.

Table 1.—Cetaceans reported from the shelf edge region of the northeastern U.S. OCS. Data from CETAP field studies, November 1978–January 1982.

Species	Common name	No. of sightings
Mysticetes—baleen whales		
Balaenoptera physalus	Fin whale	91
B. acutorostrata	Minke whale	34
B. borealis	Sei whale	27
Megaptera novaeangliae	Humpback whale	6
Eubalaena glacialis	Right whale	3
Odontocetes—toothed whales		
Tursiops truncatus	Bottlenose dolphin	531
Globicephala spp.[1]	Pilot whales	347
Grampus griseus	Grampus	332
Delphinus delphis	Saddleback dolphin	197
Physeter catodon	Sperm whale	156
Stenella coeruleoalba	Striped dolphin	48
Stenella spp. (spotted)[1]	Spotted dolphin	27
Lagenorhynchus acutus	Whitesided dolphin	22
Phocoena phocoena	Harbor porpoise	17
Mesoplodon spp.[1]	Beaked whales	6
Orcinus orca	Killer whale	3
Ziphius cavirostris	Goosebeaked whale	3
Lagenorhynchus albirostris	Whitebeaked dolphin	3
Hyperoodon ampullatus	Northern bottlenose whale	1
Pseudorca crassidens	False killer whale	1
Unidentified large whales[2]		144
Unidentified small whales[2]		520
Total sightings		2,519

[1] Identification to genus level only due to difficulty in field identification and/or unresolved taxonomy.
[2] Categories used to group unidentified or partially-identified sightings: Large whales, ≥25 feet (7.6 m) in length; small whales, <25 feet (7.6 m) in length.

Species Present

In the 39 months of field studies from November 1978 through January 1982, 2,519 cetacean sightings were reported from the defined shelf-edge region. These sightings are listed in Table 1 by species or species groups, along with two categories into which unidentified or partially identified sightings were grouped. Twenty species or species groups were reported. Of these, 12 were common (10 or more sightings) and 8 were uncommon or rare (<10 sightings). Sperm whales and fin

[1]Final Report of the Cetacean and Turtle Assessment Program, University of Rhode Island, to the Bureau of Land Management, U.S. Department of the Interior. Ref. No. AA551-CT8-48, 568 p.

Table 2.—Estimated abundance, biomass, and food requirements for cetaceans in the shelf edge region of the northeastern U.S. OCS.

Species		Abundance estimate[1,2] (No. +/− 95% CI)	Total biomass (t)	Percent of total cetacean biomass	Weight[3] (t)	Food requirement[4] (t/year)
P. catodon	sp	215 +/− 256	4,300	16	20.0	6,016
	wi	65 +/− 197	1,300	18		
B. physalus	sp	292 +/− 426	8,760	33	30.0	10,250
	wi	60 +/− 102	1,800	24		
B. borealis	sp	237 +/− 327	3,081	12	13.0	3,686
	wi	0	0	0		
B. acutorostrata	sp	47 +/− 57	212	1	4.5	330
	wi	0	0	0		
H. ampullatus	sp	9 na	42	<1	4.7	65
	wi	0	0	0		
Unidentified large whales	sp	2 +/− 6	41	<1	[5]20.5	44
	wi	0	0	0		
T. truncatus	sp	6,431 +/− 4,001	965	4	0.15	4,320
	wi	1,458 +/− 1,885	219	3		
Globicephala spp.	sp	6,823 +/− 6,934	5,800	22	0.85	19,137
	wi	2,693 +/− 3,817	2,289	31		
Grampus griseus	sp	3,543 +/− 4,350	1,205	5	0.34	3,952
	wi	364 +/− 1,254	124	2		
D. delphis	sp	13,881 +/− 19,734	902	3	0.07	8,652
	wi	15,703 +/− 24,071	1,021	14		
Stenella spp.	sp	13,210 +/− 11,334	713	3	0.05	4,317
	wi	3,754 +/− 3,004	203	3		
L. acutus	sp	1,231 +/− 1,931	148	<1	0.12	570
	wi	0	0	0		
P. phocoena	sp	140 +/− 163	6	<1	0.05	.34
	wi	15 +/− 34	1	<1		
Unidentified small whales	sp	1,504 +/− 2,206	331	1	[5]0.22	2,593
	wi	2,050 +/− 7,529	451	6		
Total	sp	47,565	26,506			63,966
	wi	26,162	7,408			

[1] Estimates based on individuals sighted at or near the surface and do not account for animals missed due to submergence. Additional discussion in text.
[2] Estimates and biomass data shown for peak values in spring (sp) and minimum values in winter (wi).
[3] Weight values are from Kenney et al. (text footnote 3).
[4] Calculation based on 6 months at high spring abundance and 6 months at low winter abundance. Definition of seasons follows calendar conventions, e.g., spring = 20 March–20 June.
[5] Estimated body weight for this grouping is a weighted mean from the identified large or small whales.

whales were the most common large whales present. The majority of small whale sightings were made up of four species (or species groups): *Tursiops truncatus, Globicephala* spp., *Grampus griseus,* and *Delphinus delphis.* Together these six taxa made up 89 percent of the identified sightings.

Abundance and Biomass

Table 2 summarizes abundance and biomass data for cetaceans in the shelf-edge region. These abundance estimates are based on aerial survey data with calculations following the methods of Burnham et al. (1980). Because these data are based solely on aerial surveys in a rigorously defined census mode, they are from a subset of the total data given in Table 1. Several differences will be noted. For example, aerial observers pooled all sightings within the genus *Stenella,* since species were virtually indistinguishable in the field. Also, while humpback whales, *Megaptera novaeangliae,* and right whales, *Eubalaena glacialis,* are known to occur in the area (Table 1), none were sighted on census tracks, and are therefore not included in Table 2.

These data suggest that during the season of peak abundance, spring, the shelf-edge region may be inhabited by 47,565 individuals with a combined biomass of 26,506 t. This inhabitance is seasonal, and the low value for estimated biomass in winter is about 28 percent of the spring season high. Averaged over the whole year, three species or species groups, *P. catodon, B. physalus,* and *Globicephala* spp., constitute 75 percent of the total cetacean biomass. Five more species or species groups, *B. borealis, T. truncatus, Grampus griseus, D. delphis,* and *Stenella* spp., each accounting for 3-9 percent of the total biomass, bring the total to 99 percent. The remaining species together account for about 1 percent of the total biomass. (This treatment does not include the two unidentified whale categories.) Therefore, of the 20 species reported, three species form the principal component of the cetacean biomass, and eight species account for nearly the entire biomass.

Food Requirements: Estimated Minimum Values

The role of cetaceans in the shelf-edge ecosystem can be further described through the calculation of the food requirements of this component. Following the methods of Brody (1945) and Hinga (1979), the minimum metabolic demands, and thus the minimum food requirements, can be calculated from the following equation:

$$\text{Resting or basal metabolism } \left(\frac{\text{Kcal}}{\text{day}}\right) = 70 \times (\text{body wt. in kg})^{0.75}.$$

The conversion of caloric demand to weight value of prey species is from Sissenwine et al. (1984a):

1 Kcal/g wet weight.

The calculated annual food requirements are given in the righthand column of Table 2. Here, individual food requirements have been multiplied by the estimated abundance. The seasonal fluctuation in numbers has been accounted for in the calculations: The total requirement is based on 6 months at the high spring estimate and 6 months at the low winter estimate. This treatment achieves our aim of a concise presentation of findings, yet is consistent with the larger and considerably more detailed data set.

The summed values suggest that the minimum food requirement of the

shelf-edge cetaceans is on the order of 64,000 t/year.

Estimated Food Requirements: A Best Estimate and an Upper Boundary

The figures presented in the foregoing are thought to be an underestimate. This is due to a number of factors:

1) Metabolic rate. Our calculations provide values for basal metabolism. The actual metabolic requirements will be greater, between 1.5 and 3 times the basal rate (Brodie, 1975; Brody, 1945; Hinga, 1979).

2) Assimilation efficiency. An animal cannot utilize all of the energy in its food. Lockyer (1981) gives an assimilation efficiency of 80 percent for cetaceans, resulting in a feeding rate of 1.25 the metabolic requirements.

3) Food storage. Many cetacean species store food energy in the blubber and elsewhere for periods of reduced feeding common to their seasonal cycles. Building up this reserve requires increased food intake while in productive feeding areas. The correction for this factor very likely lies in the range of 1.25-2.00.

4) Submerged animals missed by surveys. Aerial surveys result in estimates based on individuals sighted at or near the surface. The estimates are negatively biased by individuals not sighted due to submergence. At present, this factor can only be gauged in a preliminary way. In one study, fin, humpback, and right whales were shown to spend 25-65 percent of their time at the surface (footnote 1). Short dive routines of 2-6 minutes were reported to be common in fin whales, although dives of 6-14 minutes (or longer) were also observed (Watkins, 1981). In the Caribbean, dives of an hour or more were not unusual for sperm whales, and estimates based on underwater sounds were nearly four times higher than those based on surface sightings made from a small research vessel (Watkins and Moore, 1982). This factor is clearly highly variable (Leatherwood et al., 1982), and a correction lies in the range of 1.5-5.0.

Applying the cumulative corrections, the actual requirements are almost certain to be 2-3 times greater than the calculated minimums. For species which ordinarily spend a good portion of their time submerged and also require additional food intake to build up substantial stored food reserves, the requirement could be from 6 to 16 times greater. Particularly since sperm and fin whales are shown to be a major component of the total cetacean biomass—both species with storage requirements and apparently considerable submergence times—the upward correction to our minimum estimate will be a substantial one. To arrive at a best estimate, we select correction factors from within the ranges given as follows: a) Metabolism beyond basal metabolism—2×, b) assimilation efficiency—1.25×, c) food storage requirements—1.5×, and d) noncensusing of submerged animals—2×. Summing these values yields a total upward correction of 7.5× and a best estimate of 480,000 t/year as the annual food requirement of cetaceans within the defined region.

Using a less conservative selection of correction factors and similarly summing the values (total correction = 15×) yields an upper boundary to our estimates of 960,000, or about 1 million t/year.

These estimates will almost surely be improved upon as additional data become available. For the present, they provide an advance over what has previously been known, and a useful measure of the role of cetaceans in the shelf-edge region.

Conclusions

The role of marine mammals in the ecosystem is likely greater than has been previously recognized. For the period 1979-82 (corresponds to the cetacean data), the current best estimate for the abundance of squid and finfish in the shelf waters of the northeastern United States (includes other than the defined shelf-edge region) is on the order of 3.4 million t/year (NEFC, 1983). The commercial fishery catch for this same period was on the order of 0.5 million t/year (NEFC, 1983; footnote 2). (As above, values are for entire shelf, Gulf of Maine to Cape Hatteras, and not only the shelf-edge region.)

If our assessment is correct, the food requirement of shelf-edge cetaceans is 480,000 t/year and could approach 1 million t/year. Even after all qualifications have been considered (e.g., cetaceans feeding at various trophic levels, cetaceans feeding on species other than those considered by the foregoing National Marine Fisheries Service assessments), the impact of cetaceans on the available food resource is substantial, and is likely comparable with man's take.

To relate these findings to existing values, these estimates were converted to consumption per unit surface area following the methods of Cohen and Grosslein (In press). Dividing total consumption by the shelf-edge area and assuming, for the purposes of consistency, that 1 g wet weight equals 1.25 Kcal, cetacean consumption converts to 9.7 Kcal/m²/year, with an upper estimate of 19.3 Kcal/m²/year. Calculations based on estimates given in Winn et al. (In press) yield comparable values for Georges Bank of 6.3 and 12.6 Kcal/m²/year. Allowing for uncertainties in the estimates, indications are that consumption by marine mammals in the shelf edge region is in the same range as for the Georges Bank region.

As fishery scientists and managers seek to improve their understanding of the biology of the resource and its successful management, an area of current interest is in the improved estimation of natural mortality and the partitioning of its components. Recent work has shown predation by marine mammals to be an important element (Kenney et al.[3]; Scott et al.,

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[2]The fisheries estimates are for all commercially exploited species of finfishes and squids except highly migratory species such as billfishes, tunas, and large sharks, and inshore species such as menhaden, American eel, and white perch.

[3]Kenney, R. D., M. A. M. Hyman, and H. E. Winn. 1983. Calculation of standing stocks and energetic requirements of the cetaceans of the northeast United States outer continental shelf. Natl. Mar. Fish. Serv. Rep. NA-83-FA-C-0009, 154 p.

1983; Winn et al., In press; and this paper). This factor has, for example, been recently addressed by Sissenwine et al. (1984b) in analyzing the decline of the Georges Bank herring stock.

With respect to offshore oil and gas development, the effects of man's interaction with marine mammals are not yet clear. Several preliminary studies indicate a lack of conspicuous negative impacts on marine mammals (Geraci and St. Aubin[4]; Sorensen et al., 1984). However, other parts of these same studies also suggest possible problems due to ingestion and contact, as well as long-term chronic effects (Geraci and St. Aubin[4]).

On both counts, the conservation and wise management of marine mammals is a national policy (Marine Mammal Protection Act of 1972, Endangered Species Act of 1973). In addition, the effective management of our fishery resources requires an understanding of the role played by marine mammals. The assessments reported here should contribute to a wider view of the ecosystem, and to forthcoming decisions about the management of the shelf-edge region of the northeastern U.S. outer continental shelf.

[4]Geraci, J. R., and D. J. St. Aubin. 1982. Study of the effects of oil on cetaceans. Final report to the Bureau of Land Management, U.S. Department of the Interior. Ref. No. AA551-CT9-29, 274 p.

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Behavioral Factors Influencing Fish Entrapment at Offshore Cooling-Water Intake Structures in Southern California

MARK HELVEY

ABSTRACT—Seven species account for the majority of fish entrapment by offshore cooling-water intake structures in southern California. These fishes include transient species (queenfish, Seriphus politus; *white croaker,* Genyonemus lineatus; *walleye surfperch,* Hyperprosopon argenteum; *northern anchovy,* Engraulis mordax; *and Pacific pompano,* Peprilus simillimus*) which generally encounter intakes at night, and reef-associated species (shiner perch,* Cymatogaster aggregata; *and white seaperch,* Phanerodon furcatus*) which utilize intake structures as artificial reefs. The entrapment of these species results from different behavioral activities that bring these species into direct contact with the intake water currents at times when their vision is impaired or when the presence of unusual intake hydraulics disorients their position in the flow.*

For some transient species, intake encounters appear to be the result of random movements, while for many reef-associated fishes, intake encounters may be due to directional movements toward these structures. Future research focused on identifying the mechanisms that determine these movements is recommended as the most practical approach for reducing fish entrapment.

Introduction

Fish entrapment by offshore cooling-water intake structures has generally been regarded as the result of fish attraction to these structures (Downs and Meddock, 1974; Stauffer and Edinger, 1980). However, in situ studies conducted at southern California intake structures during the middle 1970's revealed that fish entrapment was not simply a consequence of fish contacting intake water currents (Dorn et al., 1978; Dorn et al., 1979; Helvey and Dorn, 1981; Helvey and Dorn[1]). On the contrary, intake structures were found to support diverse fish assemblages with many of these intake-associated, reef fishes swimming in and out of the intake water current without incident. Based on concomitant in-plant impingement monitoring, it was also learned that these same reef species were entrapped less frequently than nonreef species. Because earlier swimming speed studies (Dorn et al., 1979) had shown that swimming performance was not a causative factor, fish entrapment began to be viewed as a function of fish behavior.

[1]Helvey, M., and P. Dorn. 1983. Entrapment susceptibility of fishes associated with an offshore intake structure: Evidence for a viable artificial reef. Occidental Coll., Los Ang., Calif. Unpubl. manuscr., 18 p.

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With this knowledge, subsequent intake studies undertaken by southern California utilities in response to Section 316(b)[2] of the 1972 Federal Water Pollution Control Act (Public Law 92-500) were designed to substantiate the interactions of both reef and nonreef fishes with intake

[2]Section 316b of the Federal Water Pollution Control Act of 1972 requires that the location, design, construction, and capacity of cooling-water intake systems reflect best available technology for minimizing adverse environmental impact.

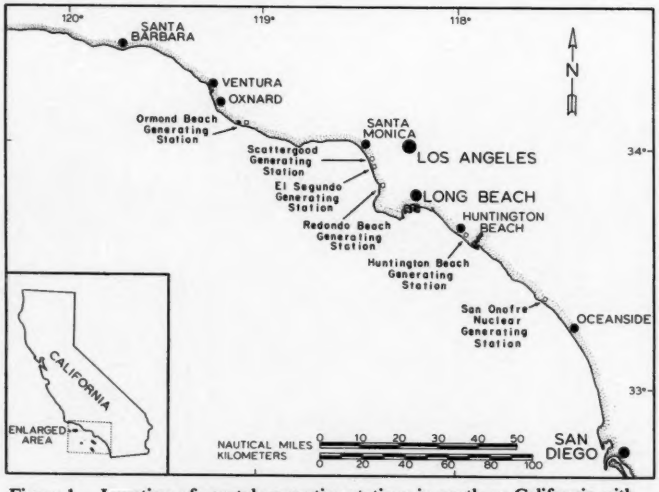

Figure 1.—Location of coastal generating stations in southern California with offshore cooling-water intake structures.

structures. These studies were divided along two lines of research: One series of studies evaluated the biological and physical factors accounting for the diverse fish assemblages residing at intakes; the other series focused on understanding the dynamics of nonreef fish encounters with intakes.

Both sets of studies generated a considerable amount of information not generally accessible that deals with the behavior of fishes interacting most often with intake structures. This paper synthesizes these findings and incorporates pertinent life history information to provide a comprehensive overview of the behavioral factors underlying fish entrapment.

Entrapment Vulnerability

Between Santa Barbara and San Diego, Calif., are six open-coastal electrical generating stations (Fig. 1). Five are operated by Southern California Edison Company (SCE) and one by the Los Angeles Department of Water and Power (LADWP). These coastal facilities use ocean water for their "once-through" cooling systems by continual withdrawal of large quantities (3.7×10^6 gpm) of seawater (Larson et al., 1979; Schuman[3]). The water is drawn through submerged velocity-capped intake structures (Weight, 1958) several hundred meters offshore (Fig. 2). During the process, juvenile and adult fishes are entrapped and subsequently impinged on facility screens.

Because intakes can be considered fish sampling devices (Hardisty and Huggins, 1975; Moazzam and Rizvi, 1980; Van der Broek, 1980), albeit biased ones (Moss et al., 1981; Stephens, 1983), accurate records of fishes unsuccessful in escaping intake water currents are kept. In a 2-year study of fish entrapment throughout the SCE system, Herbinson[4] reported 137 species entrapped by SCE open-coastal intakes. However, 95 percent of the total fish loss was attributed to only seven species representing four families (Table 1).

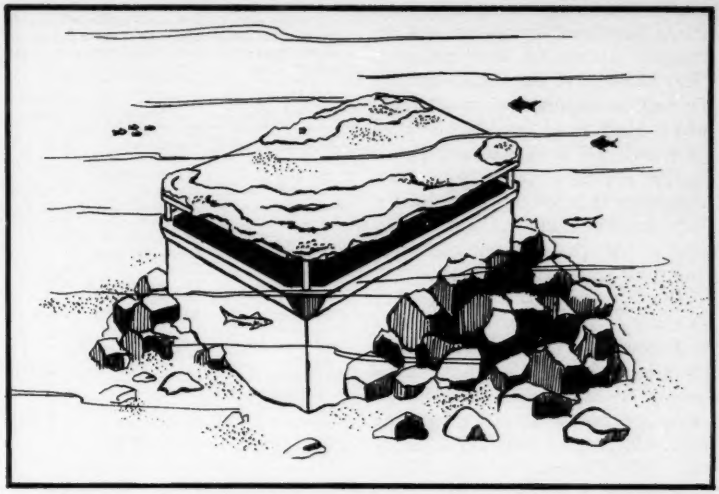

Figure 2.—A typical offshore cooling-water intake structure in southern California. Intakes consist of large vertical conduits (riser bowls) extending several meters above the sea floor and capped with a concrete slab (velocity cap). Water is withdrawn through the space between the velocity cap and riser bowl. Rock boulders strewn around the base of the structure curtail sand erosion.

Table 1.—Species most vulnerable to entrapment from October 1978 to September 1980 based on rank order of abundance for Southern California Edison Company's open coastal generating stations (adapted from Herbinson, text footnote 4).

Rank	Scientific name	Common name	No. of individuals	Percent of total	Cumulative percent
1	*Seriphus politus*	Queenfish	2,357,013	60.20%	60.20%
2	*Genyonemus lineatus*	White croaker	404,276	10.30	70.50
3	*Hyperprosopon argenteum*	Walleye surfperch	319,340	8.10	78.70
4	*Engraulis mordax*	Northern anchovy	252,363	6.50	85.10
5	*Phanerodon furcatus*	White seaperch	184,059	4.70	89.80
6	*Peprilus simillimus*	Pacific pompano	119,089	3.00	92.90
7	*Cymatogaster aggregata*	Shiner surfperch	69,560	1.80	94.70

Two sciaenids, the queenfish, *Seriphus politus,* and the white croaker, *Genyonemus lineatus,* accounted for the majority (> 70 percent) of fish entrapped between 1978 and 1980 (footnote 4). Three embiotocids, walleye surfperch, *Hyperprosopon argenteum*; shiner perch, *Cymatogaster aggregata*; and white seaperch, *Phanerodon furcatus,* composed 14.6 percent of the total fish loss. The northern anchovy, *Engraulis mordax,* and the Pacific pompano, *Peprilus simillimus,* made up another 9.5 percent of the total mortality. These seven species, with the exception of the shiner perch and white seaperch, bear little resemblance to those species residing at intakes.

Based on data combined from several studies conducted during daylight hours (Table 2), 19 species (including white seaperch; black perch, *Embiotoca jacksoni*; pile perch, *Rhacochilus vacca*; blacksmith, *Chromis punctipinnis*; kelp bass, *Paralabrax clathratus*; barred sand bass, *P. nebulifer*; señorita, *Oxyjulis californica*; and blue rockfish, *Sebastes mystinus*) are known to commonly associate with

[3]Schuman, J. 1983. Los Angeles Department of Water & Power, Los Ang. Calif. Pers. commun.

[4]Herbinson, K. T. 1981. Fish impingement inventory. South. Calif. Edison Co. Res. Develop., Rosemead, Calif. Unpubl. manuscr., 157 p.

intake structures. Interestingly, these intake-associated species are not entrapped relative to their estimated field densities in the intake vicinity. During an intensive 12-month field and in-plant study conducted between 1976 and 1977 at the Redondo Beach facility, the eight species listed above composed 95.5 percent of the intake-field population but less than 20 percent of the total fish entrapped for that same period (footnote 1).

The presence of sizable fish assemblages at intake structures clearly demonstrates that fish entrapment is not necessarily a simple function of density nor distribution as some investigators have concluded (Murarka, 1977; Haven and Ginn, 1978; Sharma, 1978; Thomas et al., 1979b; Thomas and Johnson, 1980). We do know that entrapment in southern California waters may be a function of density for some species such as queenfish, white croaker, and northern anchovy (Fig. 3). Why, then, do such entrapment disparities exist between species? The following section examines the diel behaviors of the different species interacting with intakes which may account for these varying entrapment vulnerabilities.

Table 2.—Fish species observed in more than 70 percent of the visits to three water intake structures in southern California during three intake population studies (Helvey and James, 1979; Helvey, 1981; Helvey and Dorn, 1981).

Scientific name	Common name	Intake study
Chromis punctipinnis	Blacksmith	A, C
Coryphopterus nicholsii	Blackeye goby	A, C
Rhacochilus vacca	Pile perch	A, B, C, D
Embiotoca jacksoni	Black perch	B, D
Girella nigricans	Opaleye	D
Hypsurus caryi	Rainbow seaperch	B, D
Lythrypnus dalli	Bluebanded goby	C
Oxyjulis californica	Señorita	A, C
Oxylebius pictus	Painted greenling	A, C
Paralabrax clathratus	Kelp bass	A, B, C
P. nebulifer	Barred sand bass	A, B, C, D
Phanerodon furcatus	White seaperch	B, D
Semicossyphus pulcher	California sheephead	C
Sebastes auriculatus	Brown rockfish	B, D
S. caurinus	Copper rockfish	A
S. dallii	Calico rockfish	A, C
S. mystinus	Blue rockfish	A, B, C
S. rastrelliger	Grass rockfish	D
S. serranoides	Olive rockfish	A, B, C

[1] Key: A = Redondo Beach Units 7 & 8 Intake, 12-month study between 1976 and 1977, 33 visits; B = El Segundo Units 3 & 4 Intake, 7-month study in 1978, 10 visits; C = Redondo Beach Units 7 & 8 Intake, 7-month study in 1978, 14 visits; D = Scattergood Intake, 18-month study between 1980 and 1981, 7 visits.

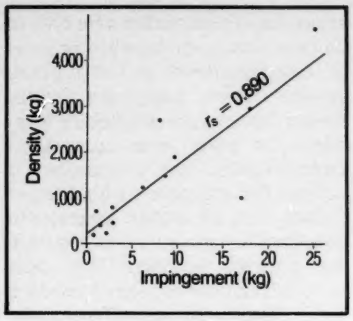

Figure 3.—Correlation between fish density (kg) in the intake area and fish impingement (kg) during hourly nighttime intervals at Huntington Beach, Calif., 1979. Results yielded a significant ($P = 0.0003$) Spearman rank correlation coefficient of $r_s = 0.89$ ($n = 66$). (From Johnson, text footnote 8.)

Fish Behavior and Interactions With Intake Approach Velocities

A large proportion of intake fish mortalities are attributed to water-column oriented, schooling fishes that are not associated with reef structures, but whose relationship to a reef is what Turner et al. (1969) considered as incidental. The term "transient" is used here to classify these nonreef fishes (e.g., queenfish, white croaker, northern anchovy, walleye surfperch, and Pacific pompano). These species differ from "reef associated" species (Turner et al., 1969), or, more appropriately, "intake-associated" species, that have a maximal or variable relationship to the reef but at least remain associated with reefs in general for almost their entire lifetime (e.g., kelp and barred sand bass, California sheephead, *Semicossyphus pulcher*; blacksmith, señorita, black perch, white seaperch, pile perch, shiner perch, and most rockfishes, *Sebastes* spp.).

Transient Fishes

Transient species are rarely seen at intakes during the day (Helvey and James, 1979; Helvey et al., 1980, 1981; Helvey, 1981; Helvey and Dorn, 1981). This is because most form quiescent schools during the day, inshore and away from reefs, only to become active and disperse offshore at night. For instance, Hobson and Chess (1976) observed queenfish in dense, inactive schools close to shore during the day that dispersed up to 1.5 km from these sites at night. This explains why Helvey and James (1979) only saw queenfish at intakes during the evening. Allen and DeMartini (1983) also reported white croaker and Pacific pompano to move offshore at night. Similarly, northern anchovy schools disperse at night (Mais, 1974) and offshore (Allen and DeMartini, 1983), although at particular times of the year they regroup into schooling formation (Mais, 1974; Squire, 1978). Walleye surfperch also form inshore schools during the day (Limbaugh, 1955; Feder et al., 1974) and disperse offshore at night (Ebeling and Bray, 1976; Hobson and Chess, 1976; Hobson et al., 1981). Using hydroacoustics, these same movements were also monitored for several species in the vicinity of the San Onofre Nuclear Generating Station on several occasions (Carlson et al., 1977; Thomas et al., 1977a, b; Thomas et al., 1979b).

These nocturnal activities appear to be primarily correlated with feeding behavior. Queenfish studies (Hobson and Chess, 1976; Hobson et al., 1981; Allen and DeMartini, 1983; Miller[5]) reveal that they feed exclusively at night on zooplankton and nekton. Walleye surfperch are also nocturnal predators (Hobson and Chess, 1976; Helvey et al., 1980; Hobson et al., 1981). Unfortunately, the feeding behavior of other transients is sketchy. Nocturnal movements and food preferences of white croaker indicate that it also feeds at night. Its prey includes polychaetes, gammarid amphipods, cumaceans, and mysids

[5] Miller, K. E. 1980. Abundances, vertical distributions, and diets of *Seriphus politus, Genyonemus lineatus,* and *Atherinopsis californiensis* (Pisces) offshore of open coastal southern California electrical generating stations. Dep. Biol., Occidental Coll., Los Ang., Calif. Unpubl. manuscr., 60 p.

(Skogsberg, 1939; Allen and DeMartini, 1983; Miller[5]; Klingbeil[6]; Ware[7]), all nocturnally emergent plankton (Hammer and Zimmerman, 1979; Hammer, 1981). Emergent zooplankton also forms part of the northern anchovy diet (Loukashkin, 1970; O'Connell, 1972), and Allen and DeMartini (1983) suggest that the nocturnal dispersion of this species is largely due to its feeding behavior.

During these evening feeding forays, many species undergo vertical shifts in the water column. Using gill nets designed for age 1+ fishes, Thomas et al. (1980b) found queenfish, white croaker, and northern anchovy distributed thoughout the water column during the evening (Fig. 4). For queenfish and white croaker, these distributions contrast substantially with their estimated daytime distributions (Fig. 5) which are normally clustered close to the bottom (Johnson[8]).

Obviously, heightened evening activities as well as associated vertical movements impose greater risks of contacting the intake water current. This may explain why fish entrapment is generally higher at night than during the day (Landry and Strawn, 1974; Grimes, 1975; Johnson et al. 1976; Thomas and Miller, 1976; Thomas et al., 1979a). In a study at the Huntington Beach Generating Station, entrapment was found to be eight times higher for all species from midnight to dawn than the remaining 18 hours from dawn to midnight (Johnson et al., 1980). Specifically, the entrapment of queenfish, white croaker, and northern anchovy was 9.5, 11.4, and 4.9 times higher, respectively, during the 6 hours between midnight and dawn.

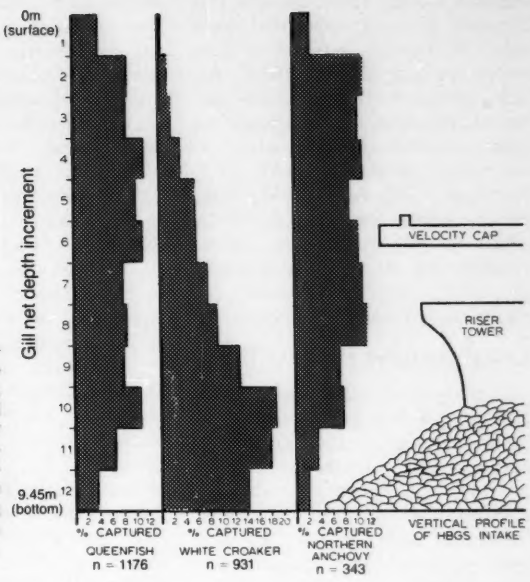

Figure 4.—Nocturnal vertical distributions of queenfish, white croaker, and northern anchovy around the Huntington Beach Generating Station (HBGS) during 36 sampling nights in 1979. (From Thomas et al., 1980b.)

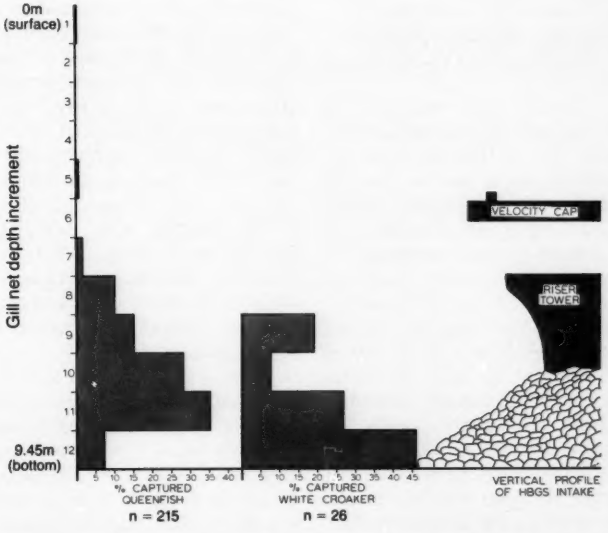

Figure 5.—Diurnal vertical distributions of queenfish and white croaker around the Huntington Beach Generating Station during 3 sampling days in 1979. (Adapted from Johnson, footnote 8).

Fish are also less apt to detect intake water currents at night. During the day, fishes active in the water column are able to visually detect and maintain station in water currents by what is known as the optomotor

[6]Klingbeil, R. A. 1972. Comparative study of the food and feeding habits of the teleostean fishes in Anaheim Bay, California. Masters Thesis, Dep. Biol., Calif. State Univ., Long Beach, 129 p.

[7]Ware, R. R. 1979. The food habits of the white croaker, *Genyonemus lineatus* and an infaunal analysis near areas of waste discharge in outer Los Angeles Harbor. Masters Thesis, Dep. Biol. Calif. State Univ., Long Beach, 164 p.

[8]Johnson, R. L. 1980. 1979 Summary report and working draft for 1980. Fish Entrapment Studies. Occidental Coll., Los Ang., Calif. Unpubl. manuscr., 181 p.

response (Lyon, 1904). Because this response depends upon the visual sense, it becomes impaired as light levels attenuate (Pavlov, 1969b; Arnold, 1974). Consequently, fishes cannot visually detect water currents at night and drift passively when encountering moving water (Ali, 1959; Northcote, 1962; Pavlov et al., 1968; Pavlov, 1969a; Pavlov et al., 1972). Thus, this physiological impairment, coupled with the nocturnal activities of these fishes, compounds the chances of nocturnal entrapment.

Intake-Associated Fishes

Intakes accommodate diverse fish assemblages that resemble those of other artificial reefs (Helvey and James, 1979). Intake fish communities also resemble other fish communities in the Southern California Bight in that they support unstable fish populations (Horn, 1980; Ebeling et al., 1980a; Stephens and Zerba, 1981; Stephens, 1983). Nonetheless, many species, particularly pomacentrids, embiotocids, labrids, scorpaenids, and serranids are generally present year round.

The continual presence of reef species appears related both directly and indirectly to feeding behavior. For planktivorous species such as the blacksmith and señorita (Hobson and Chess, 1976), intakes not only provide a visual reference but also provide a constant water current that these two species frequently orient to, perhaps for feeding purposes (Helvey and Dorn, 1981). Intake structures and the rock boulder substrata (riprap) surrounding them also support rich invertebrate populations which comprise a major component of the diet of intake residents (Helvey et al., 1980). For example, benthic feeding embiotocids (Limbaugh, 1955; Quast, 1968; Bray and Ebeling, 1975; Ellison et al., 1979) including black perch and white seaperch were found to feed directly on prey associated with intake riprap (Helvey et al., 1980; Helvey, 1981). Similarly, olive rockfish, *Sebastes serranoides*; and boccacio, *S. paucispinis*; as well as kelp and barred sand bass utilize intakes as feeding locations and consume organisms associated with the riprap including emergent plankton (Helvey et al., 1980; Helvey, 1981).

With the exception of adult olive rockfish and boccacio which actively feed during the evening hours (Hobson and Chess, 1976; Helvey et al., 1980) as well as kelp and barred sand bass which periodically feed at night (Hobson et al., 1981), most intake-associated species restrict their feeding activities to the daylight hours. For species of tropical ancestry including blacksmith, señorita, and California sheephead, this means commuting to seafloor shelters at dusk where they remain all night (Wiley, 1974; Bray and Ebeling, 1975; Ebeling and Bray, 1976; Ebeling et al., 1980b; Bray, 1981; Hobson et al., 1981). This behavior removes these species from intake water currents during the critical period when these flows cannot be visually perceived. In contrast, embiotocids, possibly because of reduced predation pressures operating within temperate communities (Ebeling and Bray, 1976; Stephens and Zerba, 1981), hover in the water column at night (Bray and Ebeling, 1975; Ebeling and Bray, 1976; Helvey and James, 1979). Such behavior naturally increases their chances of contacting intake water currents, thereby increasing their entrapment vulnerability.

There is some evidence that the entrapment of intake-associated fishes may not be strictly limited to evening hours. Johnson et al. (1976) reported marked increases in the entrapment of intake-associated species during storms, which may be related to reduced water visibilities prevalent during inclement weather. Divers have also observed intake-associated species maintaining station within intake flows to be whirled around by rare intake vortices and drawn into the intake opening during the day (Dorn et al., 1978; footnote 1). The origin of these vortices is unknown but they demonstrate that rheotropically responding fish can be occasionally overwhelmed by hydraulic phenomena.

Intake Encounters

As discussed, specific behavioral attributes associated with the activity patterns of both transient and intake-associated fishes promote their chances of encountering intake currents under suboptimal conditions. Equally important is the nature of the movements that initially bring these species to the vicinity of the intake.

Seasonality

Many species are not prone to entrapment year round because they seasonally move from intake areas. Allen and DeMartini (1983) and SCE (1981) reported that queenfish and white croaker temporarily move offshore into deeper waters during the winter months, being present at intake equivalent depths the rest of the year. These assemblages were most distinct between June and October when they formed dense nearshore populations. Johnson and Kulik[9] found similar seasonal variations for these two species in a cumulative analysis of 1971-78 otter trawl samples taken off Huntington Beach and Newport Beach, Calif. Pacific pompano undergo seasonal movements (Horn, 1970), as do northern anchovy populations which also exhibit extensive geographical movements (Messersmith, 1967). Northern anchovy movements may account for their medial occurrence in quarterly trawl surveys taken off Orange County between 1969 and 1977 (Mearns, 1977). Shiner perch also periodically form dense assemblages at intakes during the spring-fall months which corresponds to their offshore-onshore reproductive movements (Wiebe, 1968a, b).

[9]Johnson, R. L., and B. Kulik. 1980. An analysis of the depth distribution of four common nearshore fishes in the vicinity of Huntington Beach, California. Dep. Biol., Occidental Coll., Los Ang., Calif. Unpubl. manuscr., 8 p.

Nondirectional and Directional Movements

If a species is within the general vicinity of an intake, then what factors bring it into the immediate intake area? The movements of many transient species do not appear to be specifically directed toward intake structures. Based on a series of lampara net sets used to verify the species composition of hydroacoustic targets along 3 km transects, Johnson (footnote 8) found that the cumulative densities of queenfish, white croaker, and northern anchovy in the proximal vicinity of an intake were not significantly different from their densities in the distal portions of the transect course. Comparable findings were also provided in a series of gillnet experiments using mesh sizes specifically designed for queenfish and white croaker exceeding the 1+ age class (footnote 5). Analogous to the hydroacoustic lampara studies, the results statistically confirmed that the presence of queenfish and white croaker at the intake was no different than at control sites 1.5 km upcoast and downcoast.

The evidence collected in these experiments suggests that conclusions drawn from earlier hydroacoustic studies that indicated many species were attracted to intakes during normal plant operations (Thomas et al., 1978; Thomas et al., 1979a) may have been erroneously interpreted. It is conceivable that these accounts of "fish attraction" may have been based upon sonic targets of intake-associated species that were indistinguishable from transient species.

There are, however, occasions when transient species may actually remain in the intake vicinity for periods exceeding those attributable to chance. Thomas et al. (1980a) found that increases in fish density on successive nights at an intake structure peaked when the plant recirculated its heated effluent.

These "heat treatments" are periodically conducted at night as a means of removing biofouling organisms from the cooling water system at temperatures lethal to the fouling organisms. A consequence of these operations is that a tremendous quantity of prey organisms (e.g., gammaridean amphipods) are discharged from the intake into the water column (Helvey et al., 1980). This may elicit an "aggregative response" (Readshaw, 1973) in nocturnally active fishes as they encounter the plume of killed or paralyzed prey. Predatory fish remain for longer periods of time in areas where they successfully feed (Beukema, 1968; Hunter and Thomas, 1974). Heat treatments may, therefore, induce such species as queenfish, white croaker, and northern anchovy to remain in the intake area for extended periods, accounting for their increased field densities and concomitant entrapment levels (Thomas et al., 1980a).

Figure 6.—Artist's rendition of the experimental tarpaulin partially covering the rock boulder (riprap) substratum surrounding the Redondo Beach Units 7 & 8 intake structure. (From Helvey et al., 1981.)

While nocturnally active transients typically exhibit diel movements past intakes, intake-associated fishes, although invariably present, also exhibit movements. The occurrence of these movements was disclosed in an experiment that attempted to reduce substantially the carrying capacity of an intake structure by eliminating its food resources (Helvey et al., 1981). To accomplish this, prey items were either removed or covered with a tough synthetic fabric (Fig. 6). An immediate effect was the disappearance of all embiotocids and serranids from the intake area. In fact, during the first month of the experiment, the intake population was basically reduced to two planktivorous species, the blacksmith and señorita (Fig. 7). However, despite this depauperate population, entrapment levels of embiotocid and serranid species remained constant. Obviously these species continued to move between the intake and adjacent reefs in the area.

Reef fish movements may be also directional, stimulated by certain environmental cues. For example, underwater sound is known to guide the directional movements of particular teleosts and elasmobranchs (Richard, 1968; Erulkar, 1972; Popper and Fay, 1973; Nelson and Johnson, 1976). The arrival of embiotocid and serranid reef fishes at artificial reefs immediately following construction (Carlisle et al., 1964;

Grant et al., 1982) suggests that some environmental cue, possibly pressure waves emanated during reef construction, facilitates fish attraction. Specific reef sounds such as crustacean stridulation noises (Nicol, 1967; Mulligan and Fisher, 1977), fish feeding (Kim, 1977; Brett, 1979) and fish swimming motions (Moulton, 1960; Konagaya, 1980), as well as specific intake noises such as flowing water inside conduits (Ross, 1976) may conceivably attract reef fishes to intake structures.

Conclusion

If indeed particular intake or reef-associated species direct their movements in response to cues associated with intakes, entrapment must be viewed as a consequence of fish "attracted" to these structures. In this context, "fish attraction" can be regarded as a taxis, that is, a response by the fish to far-field stimuli that have directional properties (Harden Jones, 1958; Fraenkel and Gunn, 1961). These stimuli are subsequently superceded by near-field stimuli serving to reinforce the length of time fish habituate the intake (e.g., reproductive, spatial, and trophic resources).

In contrast, the entrapment of transient fishes, such as queenfish, white croaker, and northern anchovy, appears to be a random process as their movements past intakes are apparently a matter of chance. While these random events cannot be extrapolated to explain the activities of other transients, it is probable that others fit this pattern.

Despite the differences that may account for the presence of the two groups at intakes, it becomes obvious that members of both groups share a common nomadic trait. In other words, the majority of fish exhibit some type of movement. Some species are constantly transitory; others only seasonally. Likewise, some species have extensive geographical ranges while others have limited homes ranges. Nevertheless, the end result of these various movements is that both transient and intake- or reef-associated fishes continually encounter intake structures.

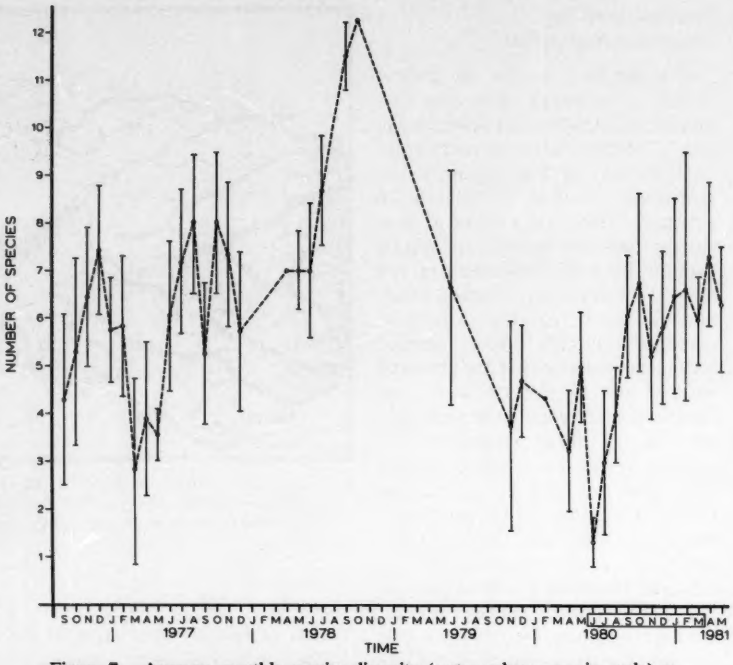

Figure 7.—Average monthly species diversity (water-column species only) at the Redondo Beach Units 7 & 8 intake structure between Sept. 1976 and May 1981. Vertical lines represent ± one standard deviation. Months enclosed within box indicate experimental period when fish did not have access to invetebrate food resources.

Therefore, because fishes will always encounter intakes, and because the physiological state of the fish (Dorn et al., 1979) as well as the quantity of water volume withdrawn (Mussalli et al., 1980) also contribute to fish entrapment, there may be a lower limit at which entrapment can be realistically reduced by means of intake design (e.g., uniform approach velocities, siting, etc.). Consequently, future research should emphasize quantifying the dynamics of fish movement past intakes. Particular attention should be given to density levels, the temporal and spatial components of these movements, and whether intakes provide directional cues. Not to be overlooked is the need to characterize unusual intake hydraulics. Understanding the precise factors underlying fish-intake encounters will allow the problem of entrapment to be viewed from a behavioral perspective. This may be the most reasonable approach if fish entrapment is to be reduced to lowest practical levels.

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Predation on Released Spiny Lobster, *Panulirus marginatus*, During Tests in the Northwestern Hawaiian Islands

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ABSTRACT—In the Northwestern Hawaiian Islands fishery for spiny lobster, Panulirus marginatus, *undersized and berried lobsters must be released. Such lobsters released in the conventional way, are very vulnerable to predation by large carnivores. Field tests showed that the white ulua,* Caranx ignobilis, *was an efficient and aggressive predator on released lobsters. Another suspected predator, the galapagos shark,* Carcharhinus galapagensis, *did not prey on released lobsters. Procedures are suggested for use by commercial fishermen that should preclude serious predation on released lobsters.*

Introduction

During 1976-82, biologists of the NMFS Southwest Fisheries Center's Honolulu Laboratory engaged in an extensive survey of the fishery resources of the Northwestern Hawaiian Islands (NWHI) (Fig. 1). In the early exploratory phase of the survey, substantial populations of spiny lobster, *Panulirus marginatus*, were discovered on several of the NWHI banks (Uchida et al., 1980). Shortly thereafter, this resource became the target of a Honolulu-based trap fishery.

Recent research has been directed toward the accumulation of knowledge which will enable sound management of the spiny lobster resource in the NWHI. Data relative to seasonal and spatial distribution and abundance, population structure, growth rate, sexual maturation, and fecundity provide the basis of a Fishery Management Plan (FMP) for the lobster fishery. The FMP prohibits the retention of egg-bearing (berried) lobsters and those <7.7 cm carapace length (CL). The regulations, which went into effect in January 1983, require that such illegal lobsters caught in the U.S. Fishery Conservation Zone around the NWHI be sorted from the catch and released alive.

On lobster fishing vessels in the NWHI, the usual procedure is to

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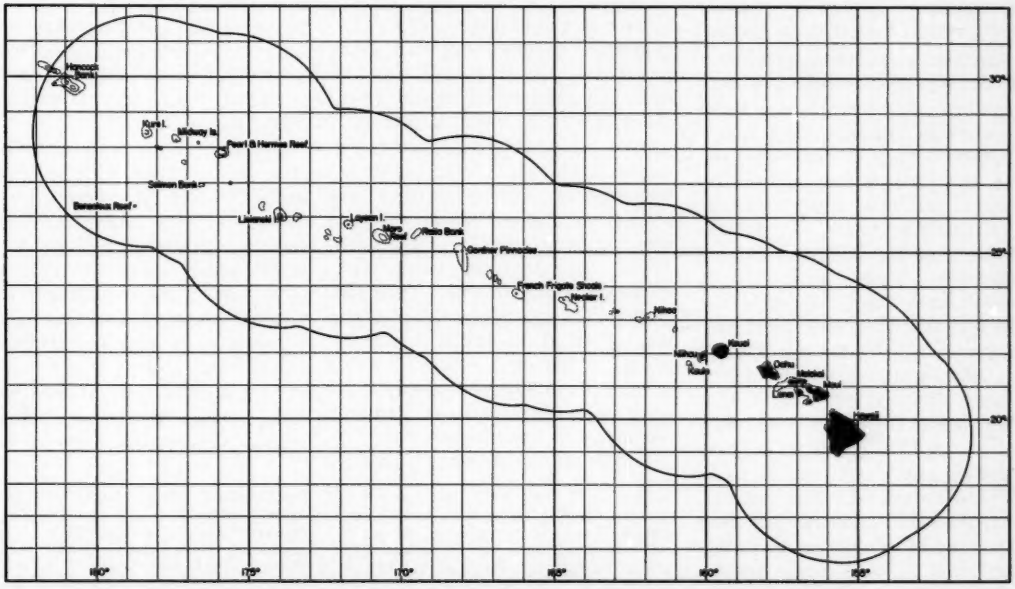

Figure 1.—The Hawaiian Archipelago including the Northwestern Hawaiian Islands.

release illegal lobsters overboard immediately after traps are hauled. Concurrently, old bait remaining in the traps is also discarded. During the period the fishery was unregulated, no estimate was available of the number of lobsters which were caught and released by commercial fishermen. However, the logbook data furnished NMFS by vessels in the NWHI fishery show that for 1983, 23.2 percent of all lobsters trapped were <7.7 cm CL (legally undersized) and 4.4 percent were berried. On grounds that are intensively fished, such as those surrounding Necker Island and Maro Reef in the NWHI, it is likely that many animals are trapped and released more than once.

The survival rate of undersized lobsters after they have been released may be of considerable significance to the long-term productivity of the NWHI lobster fishery. Thus, it is of some importance to have an understanding of the factors which affect this animal's ability to survive, grow, and reproduce normally after it has been trapped and returned to the sea. With such an understanding, it can be determined whether further regulations governing the way berried and undersized lobsters are handled by commercial fishermen are needed.

Lobsters caught in traps and subsequently released are subject to factors which may cause stress or injury and result in high mortality. These broadly include: Length of time out of the water and subsequent exposure to air, sunlight, and heat; injury resulting from handling; release on an unsuitable substrate; release in an area outside its home range; general disorientation which may make the animal more vulnerable to predation; and presence of lobster predators in the vicinity of the vessel at the time of release. Davis (1981) found that fishery-related injuries inflicted on *P. argus* resulted in a significant decrease in growth rate. Lyons and Kennedy (1981) found considerable evidence indicating that fishery handling techniques in the Florida *P. argus* fishery had a heavy impact on the stocks of sublegal lobsters, delaying or prohibiting their entry into the legal fishery.

Meyer-Rochow (1975) studied the eye of the western rock lobster, *P. cygnus*. Based on that work, Meyer-Rochow and Tiang (1981) concluded that exposure to bright light such as sunlight affects the rock lobster in several ways, all detrimental to survival, including an inability to see predators, even at moderately bright ambient light levels, inability to adjust to differing ambient light intensities, and difficulty in behaving according to a normal diurnal rhythm of activities. A study of fishery-related mortality in undersized and berried rock lobster, *P. cygnus*, showed that poor handling of lobsters before release caused high mortality (Anonymous, 1979, 1981; Brown and Caputi, 1983).

Gooding[1] reported on observations made on surface-released spiny lobsters and potential predators near Necker and Nihoa Islands in the NWHI. The objective of that preliminary study was to determine which fishes might be potential predators on surface-released lobsters. A number of previous casual observations of apparent predation on lobsters by jack crevally, *Caranx ignobilis*, or white ulua, as it is called in Hawaii, and galapagos shark, *Carcharhinus galapagensis*, had been reported by fishermen and scientists on fishing and research vessels. Thus, those two species were of particular interest. Tests were conducted in the presence of blue crevally, *Caranx melampygus*, single white ulua (no schools were seen), galapagos shark, reef whitetip shark, *Triaenodon obesus*, and gray reef shark, *Carcharhinus amblyrhynchos*. With the exception of a galapagos shark, which was observed to briefly mouth a lobster in midwater before releasing it, none of the fishes seen during those preliminary observations showed any inclination to prey on lobsters.

Sudekum[2] found that 1.5 percent of the white ulua he examined had *P. marginatus* and 1.5 percent had *P. penicillatus* remains in their guts. No lobster remains were in the *Caranx melampygus* he examined. Okamoto and Kawamoto (1980) also reported lobster remains in white ulua guts and, while conducting surveys at Pearl and Hermes Reef, they observed white ulua preying on *P. marginatus* which had fled from shelter when disturbed by divers[3]. De Crosta et al. (1984) found that guts of 65 *Carcharhinus galapagensis* he examined did not contain any lobster remains; however, 2 percent of *C. amblyrhynchos* and 11.1 percent of tiger shark, *Galeocerdo cuvier*, had *P. marginatus* remains in the gut contents.

The grouper, *Epinephelus quernus*, which is abundant in the NWHI, was considered a possible predator on released lobsters. However, although *E. quernus* are numerous in waters as shallow as 5 m at Kure Atoll and Midway (Hobson, 1980), they have not been reported in shallow waters in the southeastern part of the NWHI where the principal lobster grounds are located. In Hawaii, they are caught at bank drop-offs in depths >80 m. Seki (1984), in a study of the feeding habits of *E. quernus* caught with deep-sea handlines, did not find any lobster remains in the 67 specimens he examined. No *E. quernus* were seen during this study.

This report describes lobster release tests conducted during cruise 81-04 of the NOAA ship *Townsend Cromwell*. The cruise plan called for fishery survey operations throughout the NWHI which provided an opportunity to conduct tests incidentally when suitable conditions were encountered. Principal goals were to determine 1) under what conditions large schools of large white ulua prey on lobsters, 2) what other fishes are potential predators on released lobsters, 3) the

[1]Gooding, R. M. 1979. Observations on surface-released, sublegal spiny lobsters, and potential spiny lobster predators near Necker and Nihoa. Honolulu Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812, Admin. Rep. H-79-16, 8 p.

[2]Sudekum, A. E. 1982. Notes on the biology and feeding habits of *Caranx ignobilis* and *Caranx melampygus* in the Northwestern Hawaiian Islands. Seventh Albert L. Tester Memorial Symposium, Univ. Hawaii, Honolulu, April 1982. Abstr.

[3]Henry Okamoto, Hawaii Division of Aquatic Resources, 1151 Punchbowl Street, Honolulu, HI 96813. Pers. commun., December 1981.

probability of lobsters surviving predation when they are released at the surface and descend to the bottom in the presence of potential predators, particularly large white ulua, and 4) if lobsters contained in a bag from which they can be released at the bottom are less vulnerable to predation than when they are released at the surface and fall to the bottom.

Procedures

Tests were conducted at Maro Reef, Pearl and Hermes Reef, and Midway (Table 1). The lobsters used in most of the tests had been trapped at either Necker Island, Gardner Pinnacles, or Maro Reef during lobster resource surveys which were concurrently being conducted. The trapped lobsters were held in the vessel's baitwell. Lobsters maintained under these conditions and fed cut fish remain in apparent good condition for several weeks. The animals were removed from the tank just before a test release. At Midway four tests were conducted with lobsters which had been hand captured in the immediate area shortly before testing. The smallest lobsters available were used. However, many of the animals, especially for the tests at Pearl and Hermes Reef, were considerably larger than the minimum legal retainable size. Three scuba-equipped observers carried a 16 mm movie camera and a 35 mm still camera.

At Maro Reef and Pearl and Hermes Reef, diving operations were conducted from the *Townsend Cromwell* while the ship was anchored. A standby diver-observer in an inflatable boat maintained position over the underwater observers. A system of hand signals was used by the divers to communicate with the surface observer who monitored the underwater operation through a lookbox or dive mask and relayed instructions to personnel on the vessel to lower the bag or release lobsters. The release bag consisted of a 1.85 × 1.85 m piece of loosely woven plastic mesh material with a grommet in the center. The line to lower the bag was tied to the grommet. The lobsters were placed on the material, and the four corners drawn up forming a bag and tied together with a slipknot using the line leading from the grommet which passed inside of the bag. A 2.3 kg lead weight was attached to the grommet and hung outside and below the bag. When the suspending line was jerked by a diver from a position 5-6 m above the bag (Fig. 2), it opened and released the lobsters. The combination of plastic mesh material, which did not trap air, and the weight permitted the bag to be lowered quickly. For some tests, the lobsters were dropped in batches from the deck of the vessel, similar to the manner in which they would be released from commercial fishing vessels. However, when animals were released in this way, they usually became so widely scattered as they descended, that it was difficult or impossible to observe and photograph subsequent events. If the bag was hung about half way to the bottom and opened by a diver from a position 5-6 m above it, the lobsters were not as widely dispersed, thus permitting far better control of the tests, and more opportunities to observe and photograph predator-prey interactions. Bottom releases using the bag were not actually on the bottom because the process of jerking the line to open the bag invariably resulted in the lobsters being released about 1 m above the bottom. A bag load consisted of 10-15 lobsters.

At Midway, tests were conducted from a small boat. Lobsters were carried in a net bag by one of the diver-observers and single animals were released in midwater while the two other divers observed.

Table 1.—Predation observations.

Date 1981	Local time	Dive no.	Depth (m)	Potential predators in the area: Ulua	Galapagos shark	Gray shark	Type of lobster release
Maro Reef							
7/29	1230	1	32	30-50	3		Free at surface
7/29	1345	2	32	25-40	4-5		Bag in midwater
7/30	0930	3	32	30-40	5		Bag, 5 feet from bottom
7/31	1015	4	30	15-20			Bag, 6 feet from bottom
Midway							
8/3	1330	1	15	2			Hand released from midwater
8/4	1000	2	17	2			Hand released from midwater
8/4	1030	3	17	2			Hand released from midwater
8/5	1400	4	15	1		5	Hand released from midwater
8/6	1430	5	12	2			Hand released from midwater
Pearl and Hermes Reef							
8/8	0915	1	18	75-100	3-5		Free at surface
8/8	0925	1	18	75-100	3-5		Bag in midwater
8/8	0935	1	18	75-100	3-5		Bag on bottom
8/8	1015	2	18	75-100	Several		Bag in midwater
8/8	1025	2	18	75-100	Several		Bag on bottom
8/8	1055	3	18	75-100	Several		Bag in midwater
8/8	1110	3	18	75-100	several		Bag on bottom
8/9	0900	4	18	75-100	Several		Bag in midwater
8/9	0915	4	18	75-100	Several		Bag on bottom
8/9	0955	5	18	75-100	Several		Bag in midwater
8/9	1005	5	18	75-100	Several		Bag on bottom

Results

Maro Reef

The tests were conducted on the western side of Maro Reef in an area characterized by numerous 5-11 m pinnacles rising from depths of 30-34 m. The ship was anchored between the shallower areas in about 30 m. On the evening before the first predation tests, a 37 kg white ulua was caught by trolling in a school of large ulua in this area. It had a spiny lobster (8.6 cm CL) in its stomach.

Dive 1

The cage was suspended about 6 m

Figure 2.—Lobsters being released close to the bottom.

below the surface, and the diver-observers maintained about the same depth. There were 30-50 ulua estimated at 14-36 kg milling about in the immediate vicinity of the divers, and three 1.2-2 m galapagos sharks were circling well outside. On this dive, as on all subsequent dives during the cruise, the ulua did not show any signs of fear of the divers. Frequently they would swim within a few inches of an observer, or even touch him as they passed. Such was not the behavior of galapagos sharks, particularly the smaller ones, which usually stayed well away from human activity. Most of the lobsters released during the experiments at Maro Reef were <7.8 cm CL. Three lots of five lobsters each were released at the surface. As on previous experiments (Gooding, footnote 1), the lobsters did not swim (tail-flip) toward the bottom as is characteristic of spiny lobsters, but descended limply with tail slightly curled and legs spread. The ulua milled about among the sinking lobsters, and followed them to the bottom. Of the 15 lobsters released, we saw only 1 eaten by a fish. The lobster was taken in midwater and eaten tail first. Because of the wide scatter of the falling lobsters and reduced visibility due to turbid water during the dive, we were not able to make satisfactory observations in midwater nor were we able to see what became of the lobsters when they reached bottom.

Dive 2

Observations were made from the bottom. Water clarity had improved and because of the reflection from the sandy substrate, light conditions were better than in midwater. The bag containing 15 lobsters was opened about 5 m from the bottom. About 30 large uluas surrounded the bag as it was lowered from the ship. When the bag was opened, the fish immediately swam among the falling lobsters and nosed the lobsters as they were descending. No lobsters were eaten in midwater. About 8-10 lobsters landed in a group on the sandy bottom and quickly formed a close circular phalanx with their heads and antennae facing out, similar to the pod formations described by Kanciruk and Herrnkind (1978), but on a smaller scale. The remaining lobsters landed singly and assumed a more or less upright defensive posture, folded the tail beneath them, and moved the antennae in all directions (Fig. 3). The bottom was coral rubble or sand and afforded no shelter in the immediate vicinity. The lobsters did not attempt to leave the area. During the 10 minutes of bottom time which remained for the observers, the ulua showed relatively mild interest toward the lobsters. When a fish came close, the lobsters that landed singly would rear up and extend their antennae in the typical defense posture, always keeping their tails curled tightly in a protected position. Those forming a phalanx offered what appeared to be an effective defense, their vulnerable tails protected from attack. During the time available for observation, no lobsters were taken by the fish.

Dive 3

The next morning when about 30-40 large ulua were present, the bag containing fifteen <7.8 cm CL lobsters was opened about 1.5 m from the bottom. The fish showed strong interest in the bag as it was lowered, and when the lobsters were released, the fish immediately swam among them. When the lobsters reached the bottom, groups of two to three lobsters formed several small defensive groups and several single animals took on the characteristic defensive posture and behavior. The fish showed much more interest in the lobsters than on the previous test. Individual lobsters and members of a group were frequently flicked around or nosed by the fish. Several times we took

lobsters from the bottom and re-released them by hand about 6 m from the bottom. Several ulua would immediately follow the falling lobsters; however, no lobsters in mid-water were ingested by the fish. After about 15 minutes and just before the observers had to ascend, two lobsters on the bottom were eaten in rapid succession by two different fish. This was the first time we were able to clearly observe predation and the associated behavior. It became clear that the frequent nosing and flicking about of the lobsters were attempts by the fish to place the lobster in a position where it could either be grabbed sideways and afterwards mouthed into a tail-first position and swallowed, or initially taken tail first and swallowed whole (Fig. 4). After being swallowed, the lobsters' antennae remained protruding from the two fishes' mouths for some time.

Dive 4

The next morning, the ship was anchored in the same general area and 15 bagged lobsters were released 1.5 m from the bottom at a depth of 32 m near 15-20 medium-sized (14-18 kg) ulua. The lobsters, singly or in groups, displayed the characteristic defensive behavior. The ulua showed considerable interest in the lobsters. The flicking and nosing action was successful in breaking up two small groups of lobsters; however, during the time we were able to remain on the bottom, no lobsters were eaten or taken into a fish's mouth.

Midway

The tests were conducted from a small boat outside the barrier reef to the south of Sand Island in water 12-18 m deep. The procedure was for one diver-observer to hand-release a single lobster at a time in the presence of the potential predators. There were never more than two ulua present at once during the tests.

Dive 1

Two 18-28 kg ulua were in the area. The two lobsters which were released had been hand-caught a short time before in the same area. The first (about 8.0 cm CL) was released about 9 m from the bottom. It flipped its tail rapidly moving towards the bottom, pursued by both fish, and was caught sideways and swallowed tail first, just before it reached the bottom. Shortly afterward, a second lobster (about 6.0 cm CL) was released 6 m from the bottom. Just as it reached bottom, the same fish caught it and swallowed it tail first. The ulua continued to swim around in the area with two antennae protruding from its mouth until the observers surfaced.

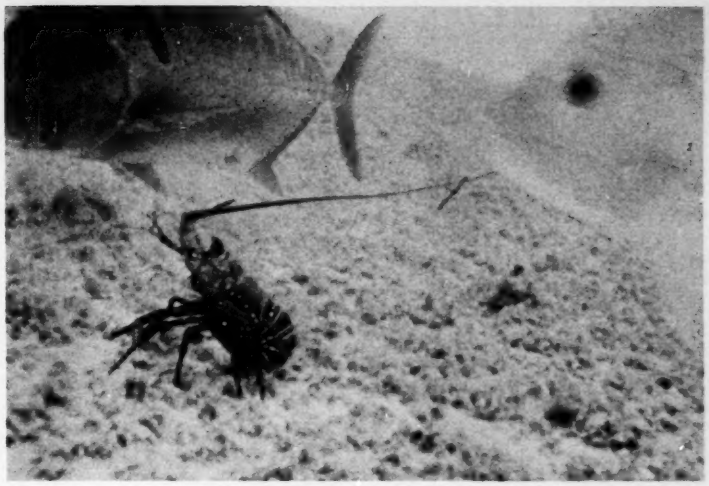

Figure 3.—Lobster in defensive posture.

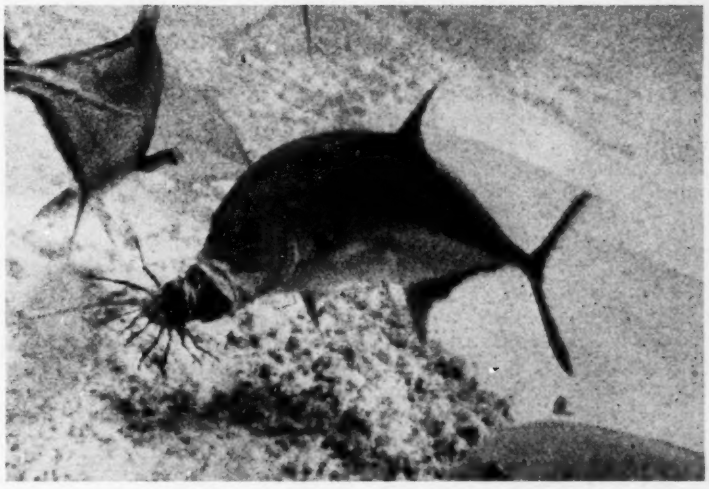

Figure 4.—An ulua swallowing a lobster tail first.

Dive 2

Two 18-28 kg ulua started circling as soon as we entered the water. One observer carried two lobsters (7.5-8.0

Figure 5.—An ulua attacking a lobster which has just landed on the bottom and has been unable to assume a defensive posture.

cm CL) which had been held in the *Townsend Cromwell's* baitwell. The first lobster was released about 8 m from the bottom. It started falling limply and was eaten tail first by one of the fish. When the other lobster was removed from the bag, the same ulua rapidly swam over, took the lobster from the diver's hand, and swallowed it.

Dive 3

In the same area as the previous dive and about 30 minutes later, the ulua that had taken the lobster from the diver's hand was still present. The antennae that had been protruding from its mouth were no longer visible. The other fish was not in sight. A lobster (about 8.5 cm CL), caught in the area a short time before, was released 8 m from the bottom and started a rapid tail-flip descent for the bottom. The fish took the lobster tail first and ate it. The swallowing process was noticeably slower with this lobster, the third eaten by the same fish within 45 minutes. When a fourth lobster of about the same size was released a few minutes later, the ulua, with the antennae of the previously eaten lobster still protruding from its mouth, followed the rapidly swimming lobster to the bottom, gave it a nudge, swam away, and showed no more interest. Apparently, three lobsters were all it could handle within that period.

Dive 4

A test was run the following day in the same general area 15 m deep where five gray reef sharks and one 18-23 kg ulua were present. A slightly undersized lobster which had been held in the ship's baitwell was released about 6 m above the bottom, then retrieved and re-released five times. The lobster elicited very little interest from the ulua or the sharks on any of these descents. The sharks left the area after a few minutes.

Dive 5

Shortly afterward, two ulua (of about 18 kg) were located in 12 m of water several hundred meters away. A 7-8 cm lobster which had been held in the *Cromwell*'s baitwell was released about 6 m from the bottom. Both fish attacked the lobster as it fell. One fish mouthed it several times, each time getting it sideways. The other fish, on a single pass, swallowed it tail first. During the following 15 minutes, more 7-8 cm CL lobsters were individually released in midwater about a dozen times. The same two ulua continued to show interest, following the lobsters to the bottom each time, but no more lobsters were eaten. Afterward, a speared wrasse, *Thalassoma* sp., about 20 cm long was released. Both fish pursued it and one ate it.

Pearl and Hermes Reef

The *Cromwell* was anchored in 19 m of water southwest of the small boat channel during the experiments. Conditions were excellent: The sea was calm, and water clarity was good.

Dive 1

An estimated 75-100 ulua, 11-45 kg, were present. The fish were bold and curious, and started milling around the divers as soon as they entered the water. There were also several galapagos sharks in the area, but they stayed well outside the center of activity, and usually were too far away to be visible.

Three tests were run during the dive. Ten lobsters each were released 1) from the ship at the surface, 2) from the bag in midwater about 8 m from the bottom, and 3) from the bag close to the bottom. On these tests and all subsequent tests, nearly all the lobsters released were >7.7 cm CL, ranging up to about 9.0 cm, the largest we had used thus far. The fish voraciously attacked and ate the lobsters as soon as they were released by all three of the release techniques. Of those animals that were released at the surface and in midwater, many were taken before they reached bottom. Those that reached bottom would immediately be surrounded by many fish trying to take a lobster. Occasionally, a fish would not be able to swallow a lobster and would spit it out, at which time many other fish would vie for it. There was often a clearly audible crunch when an animal was taken sideways. The ulua followed the bag down to the bottom, and many fish were immediately in among the lobsters as they were released. Most of the lobsters were taken before they could group into a defensive circle (Fig. 5). Those

animals that survived the initial attack were immediately surrounded by a group of fish, and within a few seconds were eaten. None of the 30 lobsters survived for more than a few minutes after release.

Dives 2 and 3

Four more releases of 10 lobsters each in midwater and two near the bottom were made during two dives in the following 1.5 hours. The feeding activity of the school was undiminished throughout the tests and none of the released lobsters survived.

Dive 4

The tests were conducted in about the same area as on the previous day and probably with the same school of 75-100 ulua. There were also several galapagos sharks and gray sharks in the outlying area.

On the first test, when ten 8-9 cm CL lobsters were released from the bag about 10 m from the bottom, dozens of fish were around the bag as it opened. The lobsters were eaten so fast that it was difficult to see or film the action. All the lobsters were gone within 10 seconds and none reached the bottom. Shortly afterward another batch was released at the bottom. Again dozens of fish crowded around, and all 10 lobsters were gone within seconds of release. For the first time we saw a large ulua take a lobster head first into its mouth (Fig. 6). This fish swam around for several minutes with the tail protruding from its mouth, apparently unable to swallow it.

Dive 5

This was a repeat of the previous tests. Ten lobsters each were released 6 m from the bottom, and on the bottom. Most of those released in midwater were eaten before reaching bottom, but the four animals that reached bottom assumed the characteristic defensive posture and survived a little longer than on previous tests with this school of fish. Although many fish continuously circled each lobster, the last one was not eaten until several minutes later. On the following test, the last individual of a batch of 10 lobsters released on the bottom managed to survive for about 5 minutes, and our impression was that the rate of serious attempts by the ulua to capture lobster had decreased noticeably. On these last tests, it was evident that in this school only the larger fish were eating or mouthing the lobsters. It was, however, difficult to estimate accurately the size of the smallest fish which was able to ingest lobster of the size we were releasing, but our rough guess was about 16 kg.

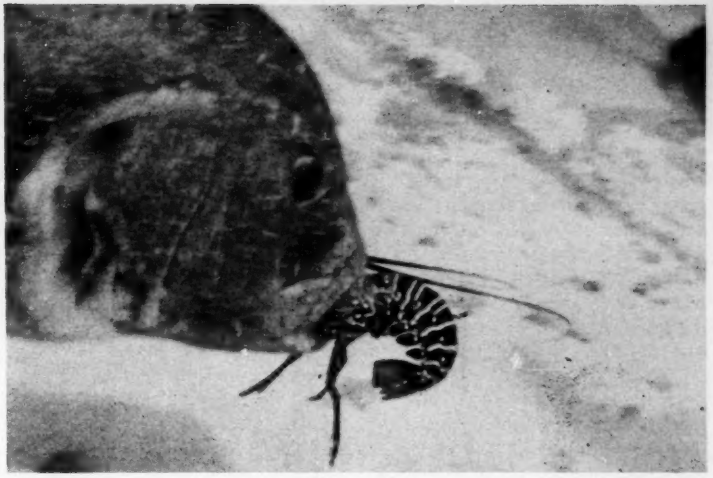

Figure 6.—A rare instance of an ulua attempting to swallow a lobster head first.

Sharks

During the tests at Maro Reef and Pearl and Hermes Reef, there usually were relatively small galapagos sharks (<2 m) in the vicinity. They always stayed well away and showed no inclination to approach released lobsters. While anchored off Necker Island one afternoon, we chummed with cut fish, and soon had several galapagos sharks ranging up to 2 m long around the vessel. While chumming continued, live lobsters tied to a light line were hung in the water among the chum. Sharks often came up to the lobsters with open mouth and turned just before reaching the lobster, or sometimes nosed it. The same thing was tried with lobster tails and heads, with the same results. However, in one test when the exoskeleton was removed from a tail and only the muscle was hung in the water, a shark took it immediately and swallowed it. The tests with a live lobster and complete tail were repeated while pouring fish blood into the water. The sharks went into a frenzy of feeding excitement, continuously nudging the lobster bait without taking them. Once the exoskeleton of a tail, from which the muscle had been removed, was taken into a shark's mouth for a moment and spat out. When fish (*Bodianus* sp.) were hung on a line, the shark bit them off and ate them without hesitation.

We did not have the opportunity to conduct experiments with *G. cuvier*, which are known lobster predators. Parrish et al. (1980) found that 11.1 percent of the tiger shark guts they examined contained remains of *P. marginatus*.

Discussion and Conclusions

Based on our experience, the presence of divers did not influence the feeding behavior of ulua toward spiny lobsters. However, galapagos

sharks probably were affected. Usually galapagos sharks will swim very close to a vessel and show no hesitancy to approach anything resembling food that is tossed or hung in the water. During the diving observations in this study, galapagos sharks stayed well away. It seems probable that the behavior of the sharks during the tests was influenced by diver activity. Had no divers been present, the sharks might have come closer to the release bag or to the released lobsters. Thus the tests with diver-observers present may not have provided reliable data on whether galapagos sharks are potential predators on released lobsters. However, other evidence indicates that apparently this species is not a predator on spiny lobsters. De Crosta et al. (1984) did not find any lobster remains in the gut contents of the 65 galapagos sharks they examined, and our attempts to induce large galapagos sharks to ingest live lobsters or parts of lobsters, except peeled tail muscle, were unsuccessful.

Tests were conducted with large schools of large, white ulua at Maro Reef and at Pearl and Hermes Reef, and with pairs and individuals at Midway. There was considerable variation in the intensity of feeding by ulua on lobsters. The 14-45 kg fish at Pearl and Hermes Reef were voracious predators on lobsters, most of which were considerably larger than animals which would be released by commercial fishermen. At Maro Reef, large schools of ulua averaging 14-38 kg showed less interest when tested with smaller lobsters that should be more easily ingested. At Midway, pairs and single fish averaging about 25 kg, fed avidly on actively swimming lobsters up to about 8.5 cm CL.

In addition to state of satiation, a fish school's potential for lobster consumption presumably is related to fish size and size of school as well as lobster size. Other factors might include behavior of the lobsters and the behavioral elements that induce excitation of the fish.

The nature of the bottom over which lobsters are released could significantly influence the degree of predator success. However, the ability of animals to protect themselves on reaching bottom is not only contingent on availability of adequate shelter, but also on the lobsters' physical condition. Impairment to walking legs or antennae, or to an animal's physiological state would be detrimental to locomotion, or ability to adjust rapidly to the different environment.

Our observations were mostly made over bottoms which afforded little shelter. The test lobsters were apparently in good condition. However, except for those animals at Midway which were released shortly after capture, the test lobsters had been held in tanks for periods up to 2 weeks. The recently caught lobsters usually tail flipped to the bottom when released in midwater, whereas animals that had been held in captivity for some time always drifted limply to the bottom.

Brown and Caputi (1983) noted that *P. cygnus*, which had been exposed to air in direct sunlight for more than 30 minutes, drifted to the bottom with legs spread-eagle and tail either curled or extended on being returned to the water. Our test lobsters had not experienced such extreme exposure, but nevertheless, this markedly different behavior may indicate that lobsters which have experienced prolonged captivity are handicapped by an inability to adjust rapidly to a sudden reintroduction into their natural environment. Such animals may have a survival disadvantage compared with lobsters which are released shortly after capture. However, tests at Midway with recently caught lobsters that swam rapidly towards the bottom showed that they were also very vulnerable to ulua predation.

Clearly, white ulua are very effective predators on released lobsters. In the NWHI, a large school of feeding fish probably has the potential to consume a large percentage of the lobsters released freely at the surface from a commercial fishing vessel.

One way to safeguard most lobsters might be to release the animals from a bag near the bottom when there is reasonable assurance that white ulua are not in the vicinity and the substrate affords shelter. Since depths on the NWHI banks are too great to visually check the bottom type, such releases should be over known lobster fishing grounds. If the day's catch of lobsters below the legal minimum size were held in circulating tanks, handled with reasonable care, and a suitable time and place when ulua were not in the vicinity was chosen, this procedure should be effective. If followed, it is unlikely that predation from ulua during trap fishing would be detrimental to lobster populations on the NWHI grounds.

However, such a procedure may not be very practical. It is questionable that fishermen, after a long, hard day of hauling traps would be willing to devote the time and effort necessary to protect the released lobsters effectively. In addition, predation is probably not the principal hazard lobsters are exposed to when they are captured and released in the NWHI fishery. A recently completed study of fishery induced mortality in undersized rock lobster, *P. cygnus*, in the Western Australian fishery (Anonymous, 1979, 1981; Brown and Caputi, 1983) showed that there was a mortality of 15 percent of all undersized lobsters if they were transported more than 100 m away from their home reefs. The Australian work and that of Davis (1981) working with *P. argus*, showed that the more frequently lobsters were handled, the more damage they suffered, i.e., loss of appendages, exposure, etc. Physical damage increased mortality or decreased growth rate which prolongs the undersized period, and increases the toll of natural mortality in the population before the lobsters are recruited into the fishery at legal size. Brown[4] found that for average damage (1.5 appendages lost) and average exposure to the air (8 minutes) the mortality for undersized

[4]Rhys S. Brown, Western Australian Marine Research Laboratories, Perth, Australia. Pers. commun., August 1982.

P. cygnus was approximately 15 percent. If these results can be extrapolated to the NWHI *P. marginatus* fishery, the inevitable handling which trapped and released lobsters undergo may eventually result in far greater mortality from displacement, physical damage, and exposure than the threat posed by white ulua predation.

The problem begins when undersized and berried animals are captured in the traps. In the Western Australia *P. cygnus* fishery, unobstructed escape gaps are required in all traps (Bowen, 1971). They found that with the currently required 5.4×30.5 cm escape gap, about 80% of all undersized lobsters (<7.6 cm CL) escape. Recent research indicates that if the gap widths were increased to 5.5 cm, escapement would increase. Their data show that with escape gaps the catch of legal-sized lobsters is not reduced (footnote 4).

A recent study with *P. marginatus* (Paul, 1984) essentially corroborates the Australian experience on the efficacy of escape gaps. Working with three types of gaps (all 6 cm wide), Paul found the overall average escapement of lobsters <8.1 cm CL was about 60 percent.

In the NWHI lobster fishery, if the numbers of undersized lobsters landed on fishing vessels were significantly reduced by requiring that traps be provided with escape gaps of specified dimensions, the potential mortality from exposure and handling as well as predation might be so reduced that no measures to directly protect lobsters from predation would be needed.

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Exploitation of California Sea Lions, *Zalophus californianus*, Prior to 1972

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Introduction

This article summarizes the results of an investigation made into historical sealing activities on the California coast and Channel Islands. Of primary interest were the numbers of California sea lions, *Zalophus californianus*, killed on San Miguel Island. The harvesting of the northern or Steller sea lion, *Eumetopias jubatus*, is also discussed. Literature was reviewed for records on the number of sea lions taken for commercial purposes. Many other potential sources of information on numbers of animals killed were also investigated. A summary of take levels is given in Table 1.

Table 1.—Summary of sea lion (*Eumetopias* and *Zalophus*) kill, 1800–1972.

Year	Species indicated	Population level	Harvest	Source
1800–1850	Mixed	Pristine	30–70 animals/year	Ogden, 1933
1860–1870[1]	Mixed	High	9,000–15,000	Scammon, 1874
1874[1]	Mixed	Low	9,000–15,000	Bartholomew, 1967
1899	*Eumetopias*	Moderate	2,000 on Ano Nuevo Island	Bonnot, 1928b
1900	*Eumetopias*	Moderate	"Great many"	Rutter et al., 1902
1907	*Zalophus*	Low	Practically all bulls killed on San Miguel Island	Bonnot, 1928a
1909–30	*Zalophus*	Low	No organized kill but a steady drain from trimming hunters and various collectors	Bonnot, 1931
1913	*Eumetopias*	Moderate	8,000 killed	Townsend, 1918
1927	*Zalophus*	Low	400 adults and nearly every pup on San Miguel Island killed	Bonnot, 1928b
1937–39	*Zalophus*	Moderate	Organized kill for pet food in Mexican waters and perhaps off the coast of California. 180 animals killed per day	Abbott, 1939 and text footnote 4
Late 1920's–1972	*Zalophus*	Moderate to high	Commercial, sport fishing take for interference in fishing operations	Jones, 1981

[1] It was not known whether this was on an annual basis or not.

Literature Review

After a thorough review of the literature, I discovered that few reliable data have been recorded on specific numbers of sea lions harvested in California. However, several papers provide information on the extent of exploitation in a general sense and give some idea of the level to which sealing operations depleted the sea lion population.

The breeding range of *Zalophus* extends south from San Miguel Island (Bartholomew, 1967; Bonnot, 1928b) to the central Mexican coast (Starks, 1921). Rookeries of the Steller sea lion are considered to be from Santa Rosa Island north to the Bering Sea (Bonnot, 1928b; Bartholomew and Boolootian, 1960). These breeding ranges overlap on San Miguel Island (Bartholomew, 1967; DeMaster[1]), and it should be noted that references made in the literature to sea lions during sealing activities in the 1800's and into the early 1900's have not always distinguished between northern and California sea lions.

Sea lions are vulnerable primarily as breeding animals on rookeries and not as nonbreeders on hauling grounds. During the breeding season, they will remain on breeding territories or soon return if driven off. Hauling sea lions will abandon hauling areas if harassed (DeLong[2]). For purposes of simplicity, all animals above Pt. Conception are regarded here as Steller sea lions and those south of Pt. Conception as California sea lions unless otherwise specified in kill records. All animals reported without locations will be referred to simply as "sea lions." Bartholomew and Boolootian (1960) showed that an insignificant percentage of Steller sea lions occurred on southern California islands. Similarly, in censuses when the species were separated, an insignificant number of California sea lions occurred north of Pt. Conception.

Although no population estimates are available from the historical literature, both species of sea lions are reported to have been abundant along the California coast and offshore islands before 1860 (Bonnot, 1928b). In the early to middle 1800's, Russian sea otter hunters and Aleutian Indians used sea lion skins for their canoes, food, oil, and clothing. Reported Ogden (1933), "Every year from . . . 3,600 to 7,200 pounds of sea lion meat were salted down in barrels and boxes." With the advent of commercial harvest, sea lion numbers decreased steadily (Bonnot, 1928a).

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[1] DeMaster, Douglas. 1981. National Marine Fisheries Service, 8604 La Jolla Shores Drive, P.O. Box 271, La Jolla, CA 92038. Pers. commun.

[2] DeLong, Robert. 1981. National Marine Mammal Laboratory, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115. Pers. commun.

From about 1860 to 1870, thousands of seals and sea lions were harvested for oil (Scammon, 1874).

Scammon (1874) described the commercial products of sea lions; his account gives some idea of the extent of the harvest: "The testes are taken out, and with the selected spires of whiskers, find a market in China, the former being used medicinally, and the latter for personal ornaments." Scammon went on to say that, "a few years ago great numbers of sea lions were taken along the coast of upper and lower California, and thousands of barrels of oil obtained. The numbers of seals slain exclusively for their oil would appear fabulous, when we realize the fact that it requires on an average, throughout the season, the blubber of three or four sea lions to produce a barrel of oil."

If 1,000 barrels is assumed, and a minimum of three sea lions produces one barrel of oil, then these data indicate a take of about 3,000 animals. Assuming 5,000 barrels indicates a take of 15,000 animals. A more extreme estimate of 10,000 barrels increases the estimate to 30,000 sea lions, or 40,000 assuming 4 sea lions per barrel. Scammon indicated that the sea lions were not eliminated on the California shores but would soon be exterminated or "driven away to less accessible haunts."

Whiskers and "trimmings" (the testes and penises of breeding bulls) of California sea lions were still commercially valuable as aphrodisiacs in Oriental trade through the 1930's (Bonnel et al., 1979). Collectors for exhibition and scientific purposes, who worked year-round, were responsible for many California sea lion pup deaths as they took only cows (Bonnot, 1931). The principal cause of the decimation of the Steller sea lion was from the hunters who took them for "trimmings." They killed bulls in such great numbers that Bonnot (1931) expressed his surprise that there were enough left to carry on breeding.

Steller Sea Lion

Isolated accounts of northern sea lions killed in large numbers can be found scattered in the literature. From 1899 to 1902, during the height of the sea lion-salmon fishery conflict, the California State Board of Fish Commissioners requested permission to kill sea lions on Federal lighthouse reservations (Smith, 1902). It was the intent of the Commission to kill 10,000 of the presumed population of 30,000 sea lions along the California coast; however, others more familiar with the sea lion rookeries said this was an overestimation of the population size, which they believed to be less than 10,000 (Merriam, 1902). Permission was granted and soon rescinded due to protests from several Federal agencies, the New York Zoological Society, and various other groups (Bonnot, 1928a, b). The Commission, however, felt its position was justified, and a great many sea lions were killed (Rutter et al., 1902). Bonnot (1928b) reported that several thousand were killed on Año Nuevo.

Townsend (1918) reviewed a report on the sea lion question in British Columbia written by a commission appointed by the Biological Board of Canada. The report covers the years 1915-16. From this report Townsend summarizes that ". . . it appears that a bounty of $2.00 was paid on 4,074 sea lions. It is stated that '. . . at a conservative estimate there must have been 8,000 killed . . .' " Townsend (1919) later reports on the general negative attitude of salmon packers who destroyed many hundreds of sea lions annually on the Rogue River Reef for several years.

Statistics for numbers of seals and sea lions taken under a bounty system for Oregon and in raiding operations in Queen Charlotte Sound from 1921 to 1926 are reported by Scheffer (1928):

Scalps taken in the state of Oregon:
Eumetopias and *Phoca*
1921-26 8,865

Queen Charlotte Sound during May and June of each year:
Eumetopias
1921-26 7,714
1925-26 ... 1,880 (sea lion pups)

On various occasions sea lions were killed for trimmings. Professional hunters used destructive methods for harvesting; therefore, a significant number of animals killed could not be recovered. As a result, any figures given on the numbers killed anywhere in the country at that time should be supplemented by at least 10 percent in order to arrive at true figures (Bonnot, 1928a, 1931).

From 1927 to 1946 periodic censuses of sea lions were made (Bureau of Marine Fisheries, 1946).

California Sea Lions

Again, specific records of animals killed are sparse and only weakly indicate the extent of commercial harvest for California. Bonnot (1928a) wrote: "Captain H. B. Nidever of San Pedro has supplied me with the information that in 1907 and 1908 several men systematically hunted sea lion bulls at San Miguel Island and killed practically all the bulls of breeding age." Bonnot (1928b) also stated that "a large number of sea lions were killed at San Miguel in violation of the law protecting sea lions in district 19. The methods used by these men would exterminate the sea lions in a few seasons. Bulls, cows and pups were killed indiscriminately . . . ." In addition to "trimmings" hunters, sportsmen, and fishermen, sea lions were taken in unknown numbers by various collectors. From a personal investigation of Flea Island (San Miguel Island), in June of 1927, Bonnot describes the death of every pup of a mixed rookery and of nearly 400 adults. From the late 1920's until the passage of the Marine Mammal Protection Act in 1972, commercial and sport fishermen were allowed to kill sea lions that interfered with their fishing operations (Jones, 1981).

Sea lions were not only exploited for their oil, hides, and "trimmings," but also for use in dog and cat food products (Abbott, 1939; Fry, 1939).

Unpublished Information

If a pet food company used sea lions as a main ingredient in its products before 1972, it was thought that the company(s) might have contract records of the numbers of sea lions procured. Thus, six pet food manufacturers were contacted and representatives of each were question-

ed about possible use of sea lions in pet food at any time during the company's existence. None were aware of any such use of sea lions or could provide any records of sea lion harvest or purchase.

However, Nathan Lewis, a partner in the Lewis Food Company[3] that bought out Dr. Ross Dog Food in the 1940's was located and supplied the following information: Nathan and his brother D. B. Lewis bought out Dr. Ross at an auction when the company went bankrupt. The company manufactured Skippy and Dr. Ross brand dog food. Nathan Lewis said he believed that Dr. Ross had purchased boats and equipment with the intent to capture sea lions for pet food but failed to pursue this endeavor as his business then went bankrupt.

In Abbott's (1939) account of sea lions killed for pet food, he stated that the harvest occurred on the coast of Mexico under a 20-year concession from the Mexican government. Clinton Abbott was director of the San Diego Museum of Natural History from 1922 to 1946. The Museum's files[4] of Abbott's correspondence on the sea lion slaughter were accessed to uncover further details. The following is information gleaned from these letters that could be pertinent to Channel Island sea lion kill data:

December 1, 1937. To the California Fish and Game Division: Abbott stated that he had received information that the Dr. W. J. Ross Dog Food company was killing sea lions supposedly in Mexican waters. He believed that the Ross company was actually, or at least also, slaughtering sea lions off the coast of California. Abbott had been informed that three boats were operating out of San Pedro and an airplane passing over them counted a large number of seals on their decks. (In his 1939 paper he named the vessels as: the *Romancia*, a killer ship; the *Lotti Bennett*, a tender vessel; and a mother ship, the *F. S. Loop*.)

December 28, 1937. To Dr. W. J. Ross Dog and Cat Food Company: Abbott wrote to the Ross Company and asked many pointed questions about when and how many animals were killed in their operations.

January 10, 1938. To Mr. T. N. Faulconer: Abbott referred to when Mr. Faulconer had given him the names of the cannery boats, operated by Dr. Ross' company, as the *F. S. Loop* and the *Romancia*. He went on to say that the Protective Committee of the American Society of Mammalogists' secretary indicated the boats operating as sealing vessels may have actually been the following: A canning factory ship *California*, U.S. Registry 209117, and two killer boats, *Hawk* 220149 and *Port Saunders* 220150, and that they were killing 180 sea lions per day. There is no information to indicate if Mr. Faulconer was affiliated with an agency or organization.

January 19, 1938. To Mr. Clinton G. Abbott: Dr. Ross replied to Abbott's questionaire by stating the company was in "no position to make any definite statements." The letter did imply the use of sea lions as an "experimental venture."

April 19, 1938. To Abbott from Brazier Howell, Department of Anatomy, Johns Hopkins Medical School, Baltimore, Md: Mr. Howell told Abbott he obtained a figure of 180 sea lions killed per day from a newspaper article.

February 8, 1938. To Abbott from Ing. Miguel A. de Quevedo, Head of the Mexican Conservation Department: de Quevedo assured Abbott that Dr. Ross's annual permit would expire on the 10th of February. (Abbott stated this in his 1939 paper and reported that the slaughter nonetheless was continuing.)

July 13, 1938. To Joseph Grinnell, Museum of Vertebrate Zoology, Berkeley, Calif.: Abbott wrote to Dr. Grinnell that a G. E. Matlock had been hired by Dr. Ross as a "Contact Man." Mr. Matlock had told Abbott that even without a Mexican permit issued to the Ross Company, the Mexicans welcomed the killing of sea lions.

Conclusion

There are few specific data for numbers of California sea lions killed in sealing activities. References in the literature are sparse and inconclusive. Sealing activities on other species of pinnipeds are also poorly documented. Log records, if they exist, of any of Dr. Ross's sealing vessels or other known sealing ships may provide the information needed to begin to estimate the numbers of sea lions killed on San Miguel Island, other Channel Islands, and along the California coast.

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[4]Unpublished correspondence. 1937-1938. San Diego Museum of Natural History Historical Files. San Diego Museum of Natural History, P.O. Box 1390, Balboa Park, San Diego, CA 92112.

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Scarred Pacific Salmon, *Oncorhynchus* spp., at Freshwater Recovery Sites in Southeastern Alaska

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Introduction

Over 500,000 metric tons (t) of Pacific salmon, *Oncorhynchus* spp., were caught in 1979 by commercial fishermen from the United States, Canada, Japan, and the Soviet Union (INPFC, 1982). The commercial harvest in Alaskan waters alone was >200,000 t, with a primary wholesale value of more than $600 million, which makes this salmon fishery perhaps the most valuable in the world.

The presence of scarred salmon harvested in Alaskan waters and the possibility that the fish are being scarred in high-seas fisheries for other species has been a subject of interest for some time. Initially, the scars were thought to be from trawls and gillnets used in high-seas fisheries, derelict nets from these fisheries, or from drift gillnets used in a newly developed offshore squid fishery (Anonymous, 1982).

Little information was available on how many scarred salmon were being caught in Alaska. In 1957, scarred or net-marked sockeye salmon, *Oncorhynchus nerka*, made up 1 percent of total migration returning to Bristol Bay (BCF[1]). Evidence was not sufficient, however, to attribute the scars to a particular foreign or domestic fishery (footnote 1).

Since 1973, chinook salmon, *Oncorhynchus tshawytscha*, and coho salmon, *O. kisutch*, harvested in the southeastern Alaska troll fishery have had scars or marks that could have been caused by fishing gear. The Alaska Department of Fish and Game (ADF&G) began studies in 1973 to determine the incidence of scars on these fish. In 1973, 1974, and 1975, the reported incidences of scars were 1.2, 0.5, and 0.4 percent, respectively, for chinook salmon and 0.2, 0.4, and 0.2 percent, respectively, for coho salmon (Davis[2]; Seibel et al.[3]). Another study in 1974 showed that 0.19 percent of the chinook salmon and 0.08 percent of the coho salmon caught in southeastern Alaska were thought to have gill-net marks; however, subsequent review of some photographs taken in 1974 suggested that not all of the scars were caused by gillnets (ADF&G[4]).

In 1981, an estimated 1.7 percent of the chinook salmon and 2.2 percent of the coho salmon caught in the Alaska troll fishery were scarred; however, samples were taken only from vessels with scarred fish (footnote 4). Vessels without scarred salmon were not included in the sample; thus, the percentages represent upper limits of the mean incidences (footnote 4). In 1982 and 1983, 0.7 percent of the chinook salmon caught in southeastern Alaska had fishery-related scars (Seibel[5]). Of the coho salmon caught in southeastern Alaska, 0.7 percent had fishery-related scars in 1982 and 0.07 percent had fishery-related scars in 1983 (footnote 5).

Data for ADF&G studies were collected incidental to other studies, and, before 1982, no quantitative data existed for estimating changes or trends. In 1982, the Auke Bay Laboratory of the NMFS Northwest and Alaska Fisheries Center, in cooperation with other agencies, began a study on scarred salmon and collected data from fish entering freshwater during their spawning migrations. The objectives of this study were to 1) determine the incidence of scarred chinook, coho, and chum, *O. keta*, salmon at freshwater sites in southeastern Alaska and 2) determine whether differences in incidences of scars were related to species or geographic area.

Methods

Several agencies, including the ADF&G, Southern Southeast

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ABSTRACT—In 1982, data on the incidence of scarred chinook, Oncorhynchus tshawytscha; *coho,* O. kisutch; *and chum salmon,* O. keta, *in southeastern Alaska were collected at 19 freshwater recovery sites in four geographic areas. Although the number of fish with fishery-related scars differed for different areas and species, the differences were not significant. Mean incidence of scarring in each geographic area was 3.7-5.6 percent: The incidence of fishery-related scars was 0.8-1.6%; the incidence of scars from other sources was 2.7-4.0%. For all areas combined, chum salmon had the fewest incidence of fishery- and nonfishery-related scars (0.6% and 1.1%, respectively), chinook salmon were intermediate (1.0 and 2.8%, respectively), and coho salmon had the most (1.7 and 4.9%, respectively).*

[1]BCF. 1957. Report on occurrence of net-marked salmon in Alaska in 1957. U.S. Dep. Int., Fish Wildl. Serv., Bur. Commer. Fish., Auke Bay Laboratory, P.O. Box 210155. Auke Bay, AK 99821. Unpubl. manuscr., 4 p.

[2]Davis, A. 1976. Southeastern Alaska commercial troll fishery. Alaska Dep. Fish. Tech. Rep. 29, 44 p.

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[4]ADF&G. 1982. A note on observations made on scarred/marked chinook and coho salmon in the 1981 southeast Alaska troll fishery. Alaska Dep. Fish Game, Div. Commer. Fish. Southeast Region, Juneau, 9 p.

[5]Seibel, M. 1982. Biometrician, Alaska Department of Fish and Game, Juneau, AK 99801. Pers. commun.

Table 1.—Recovery of scarred salmon at freshwater sites in southeastern Alaska in 1982. N = fish caught at weir but not individually examined for scars; S = fish caught in a seine and individually examined for scars; and W = fish caught at weirs and individually examined for scars.

Recovery site	Recovery method	Species	Recovery dates	Number of fish observed	Fish scarred in each category and subtotals(%)									
					Fishery-related				Nonfishery-related				Total scarred	
					1	2	3	Sub-total	4	5	6	Sub-total	Number	%
Northern outer														
Situk River	N	Chinook	18 June-19 Aug.	528	5.9	0	0.1	6.0	0	0.4	3.4	3.8	52	9.8
Sashin Creek	W	Chinook	26 July-22 Aug.	1,088	0	0	0	0	0	0.6	0	0.6	7	0.6
Falls Creek	S	Coho	7 Oct.-20 Oct.	254	0	0	0	0	0	1.2	0	1.2	3	1.2
Ford Arm Lake	W	Coho	14 Aug.-17 Nov.	1,379	0.7	0.1	0.1	0.9	0.6	1.4	5.1	7.1	111	8.0
Politofski Lake	W	Coho	15 Aug.-14 Nov.	204	0	3.4	0	3.4	2.0	2.9	9.8	14.7	37	18.1
Sashin Creek	W	Coho	3 Sept.-21 Oct.	605	3.3	0.5	0	3.8	0	0.2	2.8	3.0	41	6.8
Medvejie Creek	W	Chum	24 Aug.-22 Sept.	1,048	0	0	0	0	0	0.1	0	0.1	1	0.1
Salmon Lake Creek	S	Chum	30 Aug.-22 Sept.	1,068	0	0	0	0	0	0	0	0	0	0
Nakwasina Sound	S	Chum	16 Sept.-24 Sept.	552	0	0	0	0	0	0.4	0.6	1.0	6	1.0
Combined sites				6,726	0.9	0.1	0	1.0	0.2	0.6	1.9	2.7	258	3.7
Southern outer														
Warm Chuck Lake	W	Coho	14 Sept.-15 Oct.	426	0.2	1.4	0	1.6	0	2.6	1.4	4.0	24	5.6
Northern inner														
Berners River	S	Coho	3 Nov.-19 Nov.	182	5.6	0.5	1.7	7.7	0.5	0.5	0.5	1.5	17	9.3
Auke Creek	W	Coho	24 Sept.-15 Oct.	455	0.4	0	0	0.4	0.7	3.7	0.4	4.8	24	5.2
Snettisham Hatchery	W	Coho	1 Dec.	118	2.5	1.7	0	4.2	0	0.9	2.5	3.4	9	7.6
Speel River	W	Coho	18 Sept.-31 Oct.	763	2.4	0	0	2.4	0	1.6	8.1	9.7	92	12.1
Sawmill Creek	W	Chum	17 July-22 Aug.	891	0.6	0.4	0	1.0	0	2.5	0	2.5	31	3.5
Montana Creek	W	Chum	4 July-25 Aug.	3,155	1.0	0	0	1.0	0	1.0	0	1.0	63	2.0
Auke Creek	W	Chum	11 Aug.-13 Sept.	251	0	0	0	0	0	6.4	0	6.4	16	6.4
Combined sites				5,815	1.2	0.1	0.1	1.4	0.1	1.7	1.2	3.0	252	4.4
Southern inner														
Andrew Creek	W	Chinook	21 July-20 Aug.	813	0.2	0	0	0.2	0	8.3	0	8.3	69	8.5
Crystal Creek	W	Chinook	9 Aug.-8 Sept.	1,087	0	0	0	0	0	0.4	0.1	0.5	5	0.5
Crystal Creek	W	Coho	30 Aug.-1 Oct.	962	1.6	0	0	1.6	0	1.0	0.4	1.4	29	3.0
Klakas Lake	W	Coho	3 Aug.-4 Nov.	537	1.3	1.5	0.7	3.5	1.5	3.2	2.2	6.9	56	10.4
Whitman Lake	W	Coho	14 Oct.-18 Nov.	1,100	0	0	0	0	0	2.3	0	2.3	25	2.3
Combined sites				4,499	0.5	0.2	0.1	0.8	0.2	2.7	0.4	3.3	184	4.1

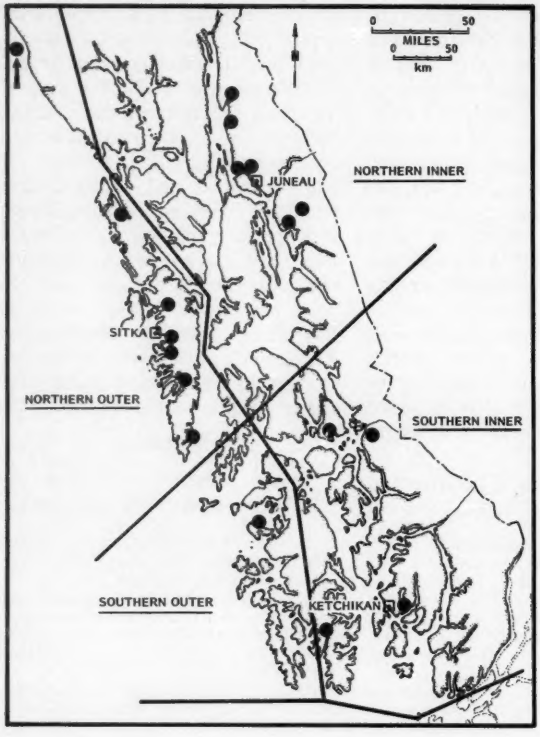


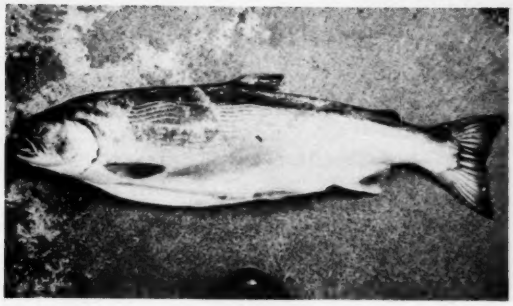
Figure 1.—Locations of scarred salmon recovery sites in four areas of southeastern Alaska.

Regional Aquaculture Association, Northern Southeast Regional Aquaculture Association, and the National Marine Fisheries Service, collected information in 1982 on scarred salmon at 19 freshwater sites in southeastern Alaska (Table 1). Each site was assigned to one of four areas based on geographic location and nearby domestic net fisheries: Northern Outer Coast, Northern Inner Coast, Southern Outer Coast, or Southern Inner Coast (Fig. 1). The main difference between fisheries along outer and inner coast areas was that the outer coast had only one major gillnet fishery, which is in the Yakutat Bay area (Larson[6]).

Data for this study were collected from salmon that either returned to

[6]Larson, P. 1982. Fishery Biologist, Alaska Department of Fish and Game, Juneau, AK 99801. Pers. commun.

Category I scars (at left) are usually caused by gillnets (apparent when the marks are similar on both sides of the fish) or by entanglement in trolling gear (when the marks are dissimilar on each side). Category II scars (bottom left) are apparent scrape marks which could be caused by abrasion received from fishing gear or from predator bites. Category III scars (bottom right) show a dorsal scrape band between the head and the dorsal fin which may be caused by abrasions with fishing gear after being hooked. Here, the dorsalmost section of the scar is exposed flesh, indicating that the wounds are fairly recent.



fish-counting weirs or were captured with beach seines at streams with no weirs. Salmon that returned to the weirs were either individually captured and examined for scars or closely examined for scars as they swam through a small opening in the weir. Fish captured with beach seines were handled and examined individually.

At each site, the number of unscarred fish and the number of scarred fish in each category were recorded by date. The scars were identified from a booklet of color photographs (ADF&G[7]) and classified into six categories (Table 2). Three categories (I-III) were designated as fishery-related scars and the other categories were designated as nonfishery-related scars, such as those attributed to handling, predators, or unknown causes. The Kruskal-Wallis test (Conover, 1980) was used to test for differences in scar incidence among species and among geographic areas.

[7]ADF&G. 1982. 1982 field operational plan for sampling chinook and coho salmon harvested in the southeast Alaska troll fishery for incidence of gear marked and scarred fish. Alaska Dep. Fish Game, Div. Commer. Fish., Southeast Region, Juneau, 13 p.

Table 2.—Standardized descriptions used at each recovery site to classify scarred salmon into categories (text footnote 7).

Category	Description
I	One or more fairly well delineated linear marks between the head and the dorsal fins, approximately perpendicular to the longitudinal body axis and encircling or partially encircling the body.
II	A series of approximately parallel marks or scrape lines over much of the body or two or more series of such marks at different angles, which may give the appearance of cross-hatching marks.
III	A fairly well delineated scrape band usually between the head and the dorsal fin, approximately perpendicular to the longitudinal body axis or angled slightly backward from the top to the bottom of the body and containing an approximately oval-shaped open wound that is normally in the upper portion of the body.
IV	Extensive descaling of ≥25 percent of one or both sides of the body but no well-delineated marks or wounds.
V	Open, gaping wounds or puncture marks anywhere on the body, either without other marks and scrapes or with adjacent, irregular "scratch" or "claw" marks but no marks as described in Categories I–IV.
VI	Scars or marks not in Categories I–IV.

Results and Discussion

A total of 17,466 salmon (3,516 chinook salmon, 6,985 coho salmon, and 6,965 chum salmon) in southeastern Alaska streams were examined for scars in 1982 (Table 3), and 4.0 percent of the fish had them: 1.1 percent had fishery-related scars and 2.9 percent had other types of scars. At most recovery sites, the incidence of nonfishery-related scars was greater than the incidence of fishery-related scars, and predators were prob-

Table 3.—Number of chinook, coho, and chum salmon sampled for scars in streams in southeastern Alaska in 1982, including incidence of total fish with scars and incidence of fish with fishery- and nonfishery-related scars.

		Incidence of Scars		
Species	Fish sampled (No.)	Total (%)	Fishery related (%)	Non-fishery related (%)
Chinook	3,516	3.8	1.0	2.8
Coho	6,985	6.6	1.7	4.9
Chum	6,965	1.7	0.6	1.1
Combined species	17,466	4.0	1.1	2.9

ably attacking salmon congregated near the streams.

Mean incidence of scarring in the four geographic areas was 3.7-5.6 percent: The mean incidence of fishery-related scars was 0.8-1.6 percent and the incidence of other types of scars was 2.7-4.0 percent (Table 1). The incidence of both fishery- and nonfishery-related scars were not significantly different ($P=0.05$) for the four recovery areas.

Although differences were not significant ($P=0.05$), chum salmon had the lowest incidence of both fishery- and nonfishery-related scars, chinook salmon were intermediate, and coho salmon had the highest incidence (Table 2). In a 1982 port-sampling study, coho salmon also had more Category I scars than chinook salmon (footnote 3), possibly because coho salmon, once hooked on troll gear, often roll and become entangled in troll lines, a behavior that is more characteristic of coho salmon than chinook salmon (Robinson[8]). A scientific observer on a troll vessel in 1982 documented the rolling of coho salmon in troll lines and provided photos of the particular scars (footnote 8). The scars caused by troll lines were similar to gill-net scars. Salmon can also be scarred when they are caught on troll gear, struggle against the fishing leaders, and either escape or are released, as chinook salmon are during closed fishing seasons. Coho salmon may have been more vulnerable than chinook salmon to scarring during domestic net fisheries for chum salmon and pink salmon, *O. gorbuscha,* because net fisheries were held in areas where coho salmon were returning to their natal streams.

Several observers at the weirs in this study believed that salmon were probably becoming scarred during nearby domestic net fisheries. For example, an estimated 5.0 percent of the chum salmon at Carroll Creek (Southern Inner Coast) were scarred during a local gillnet fishery (Freitag[9]), and 3.4 percent of the coho salmon at Politofski Lake (Northern Outer Coast) were possibly scarred during the local seine fishery (Shaul[10]). A gillnet fishery for sockeye salmon in and near the Situk River (Northern Outer Coast was suspected of incidentally scarring chinook salmon, of which 6.0 percent had fishery-related scars (Woods[11]). In another 1982 study on salmon harvested in the southeastern Alaska troll fishery (footnote 3), the incidence of scarred fish was lower than we observed, probably because fish in our study were becoming scarred during domestic fisheries as they migrated through nearshore fishing areas.

[8]Robinson, W. 1982. Fishery Biologist, National Marine Fisheries Service, NOAA, Juneau, AK 99802. Pers. commun.

[9]Freitag, G. 1982. Fishery Biologist, Southern Southeast Regional Aquaculture Association, Ketchikan, AK 99901. Pers. commun.

[10]Shaul, L. 1982. Fishery Biologist, Alaska Department of Fish and Game, Juneau, AK 99801. Pers. commun.

[11]Woods, G. 1982. Fishery Technician, Alaska Department of Fish and Game, Juneau, AK 99801. Pers. commun.

Conclusions

There were no significant differences in the incidence of scars between species or geographic areas. Pacific salmon migrate through areas where foreign and domestic high-seas fisheries are taking place; thus, the scars have many possible sources. Based on the comparison of the incidences of fishery-related scars in this study with those in the 1982 port-sampling study (footnote 3), and given the time and location of the domestic troll and net fisheries in southeastern Alaska, many of the salmon observed in this study could have been scarred during domestic fisheries. I was, however, unable to relate the incidence of scars to specific fisheries.

Any differences between species in the incidence of fishery-related scars probably resulted from comparison of species caught primarily in the troll and net fisheries, and differences in behavior of chinook salmon and coho salmon caught on troll gear. Differences between species in nonfishery-related scars are probably related to the particular recovery sites, where salmon may have different susceptibilities to predators.

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Examining Business Turnover in the Texas Charter Boat Fishing Industry: 1975-80

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Introduction

The Texas charter fishing boat industry has received much previous research attention. The research has addressed the distribution and organization of charter boat businesses, operator motivations, and socio-demographic characteristics (Ditton et al., 1977a), business costs and returns (Ditton et al., 1977a; Woods and Ditton, 1980), their fishing clientele (Ditton et al., 1977b; Mertens[1]), local and regional economic impacts (Ditton et al.[2]), and harvest (McEachron and Matlock, 1983).

Each of these studies reports results of a cross-sectional study. A cross-sectional study utilizes data collected at one point in time from a particular population to explore relationships (Borg and Gall, 1983). Our nationwide review of the literature on the charter boat fishing industry revealed that all were cross-sectional studies as well. The cross-sectional study design precludes any study of change, and consequently the extent of stability and turnover among charter fishing businesses remains unexplored. The evaluation of stability and turnover requires the use of time series data and temporal analysis. Temporal analysis is used by social scientists interested in change, process, and the dynamic aspects of social and cultural phenomena (Glenn and Frisbie, 1977).

This paper used data collected at two points in time to address the extent of turnover in the Texas charter boat industry between 1975 and 1980. If it is assumed that the best predictor of the future is the recent past, then a knowledge of trends can not only lead to a better understanding of the phenomena, but also provide managerially useful information (Land, 1983).

A large percentage of business firms in the United States are, by any classification, small. Forty-six percent have fewer than five employees (Small Business Administration, 1983). Individually, these small firms are frequently described statistically in terms of annual sales, products offered, economic effect, or geographic location (Preston, 1977). However, these statistics give little information about what small businesses are like as groups or types. Also, these statistics infer little about the characteristics that distinguish the many different groups of small firms from one another.

Based upon his study of small businesses in Buffalo, N.Y., Preston (1977) suggested a five-category classification system to better portray small business firms. He identified five business types: The rare success, small business industries, firms based on successful specialization, satellite firms, and turnover firms.

High turnover is a characteristic emphasized in every study of small business. It has been estimated that as

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The Port Aransas, Tex., charter boat fleet.

[1]Mertens, T. J. 1977. The Texas Gulf coast charter boat fisherman: A description of the population, their charter fishing participation, and opinions about their fishing experience. Dep. Rec. Parks, Tex. A&M Univ., unpubl. Master's Prof. Pap., 28 p.

[2]Ditton, R. B., R. N. Jarman, T. J. Mertens, M. P. Schwartz, and S. A. Woods. 1977. Charter fishing on the Texas coast. Unpubl. tech. rep. submitted to TAMU Sea Grant Coll. Program, 186 p.

Figure 1.—Distribution of Texas Gulf Coast charter businesses operating in 1975 and 1980, by region.

many as one-third of all small businesses vanish each year (exit), only to be replaced by an equal number of often unpromising new arrivals (entry) (Preston, 1977). He described the "turnover firm" as follows:

"Even when the optimum scale of an economic activity is relatively large, and possibilities for successful differentiation unavailable, if the pool of potential entrants is great enough and no institutional barriers prevent it, there may be a perpetual and numerous small business population composed of turnover firms, whose activities consist primarily of 'entry' followed by 'exit' ".

New businesses are created when entrepreneurs see an unsatisfied demand in the marketplace, and the corresponding opportunity to fill that unmet need. The belief that entrepreneurs are profit-motivated is widely accepted (Broom and Longenecker, 1966; Dibble, 1974). Further, those entrepreneurs motivated primarily by potential financial rewards are usually the most successful (Baty, 1974).

Financial reward has not been demonstrated as the primary motivator in the charter fishing industry. For example, the 1975 average net profit for a Texas charter fishing vessel before any interest payments and income taxes was $5,804 per boat (Ditton et al., 1977a). This suggests factors other than financial reward motivate individuals to invest in a charter fishing business. After all, the charter boat business has been characterized by some operators as "fishing all day, everyday, from your own fully tax deductible boat and getting paid for it" (Groene, 1973). When Texas charter boat operators were asked in 1975 why they became charter operators, the majority said they had not entered the charter fishing business for economic reasons. This makes charter boat businesses likely candidates for classification as "turnover firms."

Methods

An inventory of Texas charter boat fishing businesses was compiled in 1975 by Ditton et al. (footnote 2). A charter fishing boat business had to meet the following criteria to be included in that inventory:

1) Operates a vessel that is U.S. Coast Guard certified if it is more than 5 gross tons. If the vessel is less than 5 gross tons, the operator is only required to have a Coast Guard motorboat operator's license.

2) Provides the services of a boat and/or services of a U.S. Coast Guard licensed captain to take six or less people fishing (either bay and/or Gulf) for monetary remuneration.

3) Utilizes a formal advertising method such as the classified section of telephone directories, radio, television, newspapers, magazines, brochures, or an established chartering service.

Using these criteria, 88 charter boat businesses were identified and grouped regionally on the Texas coast. This 1975 inventory of charter businesses served as a baseline for this paper.

A second inventory of Texas charter boat fishing businesses was compiled during 1980 using the same methods and definitions used in the 1975 inventory (Matheusik[3]), with

[3]Matheusik, R. E. 1980. An exploratory analysis of the extent of stability and the characteristics of change in the charterboat industry on the Texas Gulf coast. Dept. Rec. Parks. Tex. A&M Univ., unpubl. rep., 42 p.

121 businesses identified and also grouped by region to enable comparison.

The descriptive data for 1975 and 1980 provide one view of the Texas charter fishing boat industry. Taken together, the two cross-sectional data sets showed an increase in the size of the Texas charter fishing industry. However, the extent of change during this period is unknown. By separating the 1975 population of charter boat businesses into three subpopulations (steadfast, dropout, and new charter businesses), we examined the extent of stability in the industry between 1975 and 1980.

The steadfast subpopulation includes those businesses that were operating in 1975 and remained in business during the 5-year study period. The dropout subpopulation includes those businesses that departed from the industry sometime between 1975 (after the first inventory was made) and 1980 for one reason or another. They were operating in 1975 but not 1980. The new business subpopulation includes those businesses that entered the industry after the 1975 inventory was made. Changes in these three subpopulations will indicate the rate of turnover, or the relative temporal stability, of the Texas charter boat fishing industry.

A high percentage of steadfast businesses indicates stability, while a high percentage of dropout and/or new businesses indicates a high turnover rate and temporal instability. The reader is cautioned to remember that the analysis reported here is based on two temporal data points.

Results

Figure 1 shows the growth in the number of operating charter fishing businesses between 1975 and 1980. Thirty-three more businesses were operating in 1980 than 1975, a 37.5 percent increase. Net change in the number of operating charter businesses between 1975 and 1980 varies by region (Table 1). While it might be assumed the industry is enjoying steady growth, looking at changes in the three identified subpopulations reveals a different picture. Of the 88 businesses operating in 1975, 46 had dropped out of (exited) business by 1980 (52 percent), and 79 of the 121 businesses operating in 1980 were new (entered) since 1975 (65 percent). Only 42 businesses operating in 1975 were still operating in 1980 (35 percent) (Fig. 2) (Table 1, 2).

Differences between regions in the percentage of steadfast, dropout, and

Figure 2.—Subpopulation changes in charterboat fishing businesses between 1975 and 1980, by region.

Table 1.—Turnover in the Texas charter boat fishing industry by region.

Region	1975 Pop.	Dropout	Steadfast	New	1980 Pop.
Freeport	27	17	10	18	28
Port O'Connor	8	1	7	3	10
Rockport	13	4	9	7	16
Port Aransas	30	21	9	31	40
South Padre	10	3	7	20	27
Total	88	46	42	79	121

Table 2.—Turnover in the charter boat fishing industry along the Texas Gulf coast.

Year	Total businesses	Dropouts (1975–80)	Steadfast (1975–80)
1975	88	46 (52%)	42 (48%)
Year	Total businesses	New businesses (1975–80)	Steadfast (1975–80)
1980	121	79 (65%)	42 (35%)

A 35-foot Hatteras for sale.

new subpopulations are shown in Table 3. The two regions with the highest dropout rates were Freeport and Port Aransas which are adjacent to the Houston/Galveston and San Antonio/Corpus Christi metropolitan areas. These two regions also had high percentages of new businesses in 1980. South Padre Island stands out as a major growth region with a low dropout rate and high entry rate. Taken together, the high percentage (52 percent) of operators who dropped out and some of the regional exit/entry patterns suggest the Texas charter boat industry is a turnover type industry.

Table 3.—Variation in net growth and percent change in subpopulations by regions.

Region	Net[1] change	Steadfast businesses % of 1975 pop.	Steadfast businesses % of 1980 pop.	Dropout businesses (% of 1975 pop.)	New businesses (% of 1980 pop.)
Freeport	+1	37	36	63	64
Port O'Con.	+2	88	70	12	30
Rockport	+3	69	56	31	44
Port Aransas	+10	30	22	70	78
South Padre	+17	70	26	30	74

[1] Net change = Businesses operating in 1980 minus businesses operating in 1975.

Discussion

Two explanations for the high turnover can be offered. The first is entrepreneurs have been entering the charter business for all the wrong reasons. Charter boat operations are conducted in a business climate characterized by high levels of competition and low profit margins. Many businesses fail in this harsh business climate. Persons wishing to enter this business and be successful should be oriented to business and motivated by concerns for profit. In an effort to rationalize the entry process, a detailed financial analysis was conducted in Texas (Woods and Ditton, 1980) and distributed in an effort to inform potential operators on how much business must be generated to break even financially.

A second explanation for the rate of turnover observed is that these businesses naturally turn over as the business environment changes or as the operator loses interest, has particular experiences, or chooses to devote his time, boat, and money elsewhere. The price of diesel fuel provides an example of how the operating environment can change. In 1975, diesel fuel sold for approximately $0.40 per gallon. By 1980 this had risen to $1.10 per gallon.

Charter fishing boat businesses follow the pattern for a turnover business as decribed by Preston earlier. To put the rate of turnover identified for this business sector in some perspective, we compared our findings with the rate of small business failures in general. The dropout rate for small businesses in general (1-4 employees) between 1978 and 1980 was 10.5 percent, or approximately 5.3 percent annually (Small Business Administration, 1983). This would result in a 1975-80 dropout rate of approximately 26.3 percent for small businesses with 1-4 employees, half the dropout rate experienced by the Texas charter boat fishing industry.

An additional consideration not reflected in the pattern of turnover identifed in each region has to do with the charter boat fishing business criteria used in each inventory. A charter business was required to meet several criteria before being considered a legitimate operation. Those not meeting these criteria would not have been classified as a charter boat operation in 1975. This was done in response to previous studies of charter boat businesses on Lake Michigan (Ditton and Strang, 1976; Strang and Ditton, 1976) where "bandit" operators were systematically excluded from study. A "bandit" was defined as someone who instantaneously responded to an opportunity to take someone fishing for financial reward. Generally, these boats were operated without licensed captains, Coast Guard certification, advertising, insurance, and required safety equipment.

However, this determination can exclude businesses that over time have accumulated experience, established a history of assisting customers catch fish, and developed a clientele of

satisfied customers that provide a source of repeat business and therefore no longer need to advertise their services. Consequently, these charter businesses would not have been identified in 1975 and counted in the 1980 inventory as steadfast operators. Although these businesses may in fact exist and satisfy the needs of their clientele, they would not generally be available to provide services for novice fisherman or tourists. Consequently, there may be a larger steadfast population of charter businesses, but they were not inventoried initially because they could not be located through public information channels. Fisherman interested in charter services would also be unable to locate those charter businesses that no longer advertise their services. It can be argued that this group of charter operators serve an established and perhaps more experienced group of fishermen, while only those charter businesses that advertise are available to novice charter fishermen or tourists.

Implications

With 65 percent of the available charter businesses having less than 5 years of operating history, a large degree of inexperience exists. This may result in lower catch rates at the expense of paying fishermen.

New and inexperienced charter operations will either survive or fail. When they fail, a new and equally inexperienced business replaces it. This new business will probably provide services of comparable quality. This same turnover phenomena may be observed with pier fishing businesses, party boats, bait businesses, and fishing tournaments.

If a region or community is to develop its marine recreational fisheries and derive the related economic benefits, efforts must be made to allow fishermen access to the relatively small population of experienced operators. Further, those communities or regions able to maintain a steadfast or continuing charter boat fleet will be in a stronger competitive position than other areas in attracting new fishermen and their monetary expenditures.

There are also implications for future research. Instead of perpetuating the continuing trend of cross-sectional studies of statewide and regional coastal charter fishing fleets, more attention to temporal analyses and the dynamics of change is needed. This requires the completion of charter boat business inventories on a regular and timely basis, e.g., every 5 years, with careful monitoring of entries and exits.

Furthermore, there is need for greater investigative depth in future studies. In addition to identifying charter operators who advertise their service generally, belong to associations, and are listed as a part of the industry (as is the current practice in most charter fishing industry studies), effort needs to be invested in locating those operators who are successful but generally invisible to the investigator's eye. Efforts need to be made to differentiate these operators from the "bandits" who become instant charter operators when faced with an opportunity for financial gain.

Acknowledgments

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The Effect of Handling or Processing Treatments on Storage Characteristics of Fresh Spiny Dogfish, *Squalus acanthias*

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ABSTRACT—This investigation has determined the spoilage pattern and iced-storage life of spiny dogfish, Squalus acanthias, *and shows how its storage life might be affected by such handling practices as 1) gutting and/or bleeding the fish immediately following removal from the water or 2) holding these fish at other than the ideal iced temperature. Well-iced dogfish have a shelf life of about 11-12 days. If gutted immediately, the shelf life can be extended about 4 days. Despite their high urea content, ammonia formation does not seem to be a problem in well-iced dogfish. However, at elevated temperatures (46.4° and 57°F), ammonia formation is much more rapid and drastically shortens the species' shelf life. A self-contained kit for quick and simple field estimation of ammonia in dogfish flesh was found useful.*

Introduction

Spiny dogfish, *Squalus acanthias*, have been fished off the northeast coast of the United States since the late 1800's. Before the synthesis of vitamin A in 1947, the rich, oily dogfish livers provided a valuable source of that vitamin, with tens and hundreds of thousands of pounds of dogfish harvested annually from the Northwest Atlantic (Jensen, 1967). Thereafter, dogfish catches continued on a small scale, providing raw materials for other industrial processes.

However, a thriving dogfish industry never developed, and the underutilized U.S. stocks flourished and were viewed primarily as a nuisance by commercial and sport fishermen because of the damage they caused to both fishing gear and catches of more valuable fishes. Dogfish control methods even received serious consideration (Alverson and Stansby, 1963).

More recently, heavy demands on world fishery stocks have nearly depleted many higher-valued and more popular species, forcing examination of alternate species and technologies for preserving their quality. The present U.S. dogfish market is small but developing (Anonymous, 1982; Dean et al.[1]). Many European countries, on the other hand, consider this species an important food fish (Ronsivalli, 1978), thus providing U.S. fishermen with export opportunities.

Based on data collected during NMFS Northeast Fisheries Center bottom trawl research surveys, minimum biomass estimates of spiny dogfish off the northeast coast of the United States have increased sharply in the last several years (Anonymous, 1983). In 1982, biomass was estimated at 900,000 metric tons (t), 2.5 times greater than the 1968-80 average. Domestic landings peaked in 1981 at 7,000 t. Based on a long-term average biomass of 300,000 t, a potential yield of 65,000 t has been estimated (Anonymous, 1983), nine times the maximum domestic harvest to date.

Simply stated, the spiny dogfish off the northeastern U.S. coast represents a greatly underfished resource. Future development of this fishery will probably depend on the strength of the export market more than on expansion of the domestic dogfish market.

Unfortunately, many U.S. fishermen are not accustomed to handling this fish with the care needed to retain maximum acceptable quality for human consumption. The image of dogfish as a "trash fish" or as a "villain" of the sea seems to lend to the poor treatment it receives from some fishermen.

Spiny dogfish, like other sharks and elasmobranchs, have a large concentration of urea (1.7 percent) in their blood and flesh (Simidu, 1961). Urease, a bacterial enzyme, degrades this urea to ammonia and carbon dioxide, and this action proceeds rapidly if dogfish are improperly handled from the time of catch. And, as the concentration of ammonia builds up, acceptability of the flesh decreases. Vyncke (1970) showed that in spiny dogfish held 5 days, ammonia increased earlier and reached higher values when the dogfish were held for 15 hours at 15°C before being iced and kept at 0°C.

Low temperature is generally considered to be the most important factor in maintaining high quality in fish. Between storage temperatures of 25°C and 0°C, every 5°C decrease yields about a 70 percent increase in time before spoilage of dogfish (Anonymous, 1981). Vyncke (1968)

[1]Dean, L. M, D. R. Ward, and J. Axelson, 1982. A preliminary study to determine the feasibility of marketing spiny dogfish in Virginia. Final Rep. Grant "01-01-10000, Mid-Atl. Fish. Develop. Found., Annapolis, Md.

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found that ammonia increased very slowly during the first 8 days of storage in dogfish which were gutted and stored in ice at 1°C immediately after capture, but increased rather rapidly after that period to reach values of 75 mg % N after 14 days.

Foreign nations accustomed to high quality dogfish products will not accept less from an imported product. Belgium denies entry to dogfish if the ammonia nitrogen concentration exceeds 55 mg per 100 g of fish (55 mg % N) as determined by an accelerated microdiffusion method (Vyncke, 1968). France has set an upper limit of 100 mg % N (chemical test unspecified).

Since ammonia development is generally considered the most obvious indicator of dogfish spoilage, the USDC Fish Inspection Service monitors it as an indicator of flesh quality. More extensive knowledge, however, of spoilage patterns of refrigerated dogfish is needed to identify all problems associated with handling. In this four-part investigation, we have examined the spoilage patterns of iced and refrigerated dogfish and how they may be affected by handling techniques. Our primary objective was to offer evidence for recommended guidelines in dogfish handling. Secondary objectives were to establish the reliability of various chemical or physical tests for assessing sensory quality and to develop a rapid quantitative test for ammonia that could be used in the field.

Treatment of Fish

Study 1—Iced Storage Life of Spiny Dogfish

Part I

Fresh dogfish, averaging 10 pounds round weight, were procured in July 1980 from a Gloucester, Mass., day boat. Fish less than 24 hours postmortem were gutted, rinsed, and iced. They were stored in standard 125-pound capacity wooden fish boxes with three layers of fish per box and three fish per layer, and with generous icing between layers. Additional flake ice was added only to the top layer of fish during the storage period to replenish melted ice. The boxes of iced fish were held in a refrigerated room at an ambient temperature of 34-37°F (1-3°C). After intervals of 0, 2, 5, 9, 12, 15, 19, and 21 days, three fish were taken from storage for testing. One fillet from each fish was used for analytical tests, the other for organoleptic evaluation.

Part II

In December 1980, dogfish caught by a day boat were landed at Point Judith, R.I. They were held at the Pt. Judith Fish Co-op[2] in 125-pound capacity wooden fish boxes with ice until they were transported to our Gloucester Laboratory 2 days later, when they were headed and gutted (H&G), rinsed with tap water, and reiced. Storage of these fish was the same as in Part I. Fish which were 3, 5, 9, 12, 16, 18, and 23 days postmortem were removed from storage for testing. Belly flap and fillet portions of each of three fish were examined separately for each test period. One fillet and corresponding belly flap of each fish were used for analytical testing, and the other fillet and belly flap were used for sensory evaluation.

Study 2—Effect of Heading and Gutting, and Gutting Only

Arrangements were made with the skipper of a Gloucester day boat in September 1981 to supply us with three lots of 1-day postmortem dogfish which were 1) gutted, 2) H&G, and 3) whole. We considered that the H&G treatment would also serve to bleed the fish. We concede, however, that the most effective method of bleeding dogfish is by notching the tail vein or chopping off the caudal peduncle. This permits the heart, if the fish is still alive, to pump out most of the blood.

Upon arrival of these fish at the laboratory, initial Torrymeter readings were made and each fish was tagged for identification. Wood boxes containing two layers of four fish each, with generous amounts of flake ice, were stored in a refrigerated room at 35°F (1.6°C). Two fish from each lot were removed for analysis after being held in ice for 1, 4, 7, 10, 15, 18, 21, and 24 days. Fillet portions only were used for testing; belly flaps were discarded. With each fish, one fillet was used for analytical tests, the other for sensory evaluation.

Study 3—Effect of Storage Temperature

In October 1982, 1-day postmortem whole, well-iced dogfish, landed in Gloucester, Mass., were received at the laboratory. Initial Torrymeter readings were made and each fish was tagged. The fish were stored in wood boxes in a single layer without ice, four fish to a box. The fish were divided into two lots, half being stored at 57°F (14°C) and half at 46.4°F (8°C). For analysis, two fish were removed from storage at 46.4°F after 0, 1, 4, 7, and 11 days and at 57°F after 0, 1, 4, 5, and 6 days. One fillet from each fish was used for analytical tests and the other for sensory evaluation.

Study 4—Rapid Estimation of Ammonia

Excess dogfish flesh from Study 3 was stored in glass jars at −20°F (−28.9°C) until analyzed.

Analytical Tests

The analytical tests performed for Part I of Study 1 included moisture, pH, ammonia, and trimethylamine analyses. Tests for Part II of Study 1 included moisture, pH, thiobarbituric acid, ammonia, trimethylamine oxide, trimethylamine, and dimethylamine analyses, and aerobic plate counts.

For Studies 2 and 3, moisture, pH, thiobarbituric acid, ammonia,

[2]Mention of trade names or commercial products or firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

trimethylamine oxide, trimethylamine, dimethylamine, and Torrymeter tests were conducted, and aerobic plate counts were made. For Study 4, ammonia was analyzed. The entire fillet or belly flap to be analyzed was finely minced and thoroughly mixed. Test methods are given below.

Moisture

A 10-15 g sample of minced flesh, accurately weighed, was dried in an oven at 217.4°F (103°C) for 24 hours to constant weight.

pH

Twenty grams of minced flesh was blended with 40 ml distilled water for 1 minute, and the pH of the homogenate was measured with a Fisher Model 320 expanded scale pH meter.

DMA, TMA, TMAO

Dimethylamine (DMA) and trimethylamine (TMA) were determined by a modification of a gas chromatographic method described by Tokunaga et al. (1977). Modification by Lundstrom and Racicot (1983) included substitution of a 9-foot × 2 mm i.d. glass column packed with Chromosorb 103 which allowed a baseline separation of DMA and TMA, and use of a nitrogen-phosphorus specific flame ionization detector. For quantitation of the amines, N-propylamine was used as an internal standard. Trimethylamine oxide (TMAO) was determined as TMA after reduction by titanous chloride (Yamata et al., 1969).

TBA Number

For determining thiobarbituric acid (TBA) reactive substances, the method of Yu and Sinnhuber (1957) was modified by the addition of disodium ethylenediamine tetraacetate (EDTA) and propyl gallate to prevent oxidation during blending. TBA number was calculated by the procedure reported by Sinnhuber and Yu (1958).

Ammonia

Ammonia (NH_3) content of the flesh was determined by the microdiffusion method developed by Seligson and Seligson (1951) and later modified by Vyncke (1968). The Chemetrics Ammonia Nitrogen Test Kit Model AN-10 was also used when a comparison of methods was desired.

Total Volatile Bases

Total volatile bases (TVB) is a measure of the total volatile amine compounds present, and it collectively includes ammonia, monomethylamine, dimethylamine, and trimethylamine (Simidu, 1961). In this study, monomethylamine was not detected in measureable quantity, and TVB was therefore considered to consist of ammonia, di-, and trimethylamine. These latter compounds, individually or as TVB, have been employed as chemical indices of spoilage in fish. There are specific methods for determining TVB; however, we did not employ them. Instead, ammonia, TMA, and DMA were ascertained separately and the contents at any given time were summed to obtain TVB. The concentration was expressed as mg nitrogen per 100 g sample or mg % N.

Torrymeter

The Torrymeter (Jason and Lees, 1971; Jason and Richards, 1975) is an electronic instrument developed by the Torry Research Station, Aberdeen, Scotland, and designed to directly assess the relative quality of fresh (unfrozen) fish by measuring changes in the electrical properties of fish flesh during storage. In Study 1, readings were taken at three consecutive positions along the lateral line, starting at the first dorsal fin and proceeding to the caudal peduncle. Readings were generally constant in the region between the two dorsal fins, but were lower at the caudal peduncle; the average of the three readings was recorded.

For Study 2, five readings were taken in about the same location midway between the two dorsal fins and averaged. That is, when a reading was taken, the meter was removed and then repositioned in about the same spot and read again, etc. The average standard deviation for five such readings was 0.80. The magnitude of this standard deviation points out the uncertainty associated with a single reading.

Chemetrics Kit Comparison With Vyncke Method

Flesh and distilled water were blended together in a Waring blender in a 1:1 ratio for 1 minute. Then, 10 g of this homogenate was combined with 190 ml distilled water and blended for 2 minutes. The homogenate was filtered with suction, and portions of the filtrate were used for ammonia determination by both the Vyncke method and Chemetrics kit method. Further dilutions of the filtrate with distilled waters were made when necessary.

Glass ampoules in the Chemetrics kit hold a premeasured color-forming reagent (Nessler reagent) sealed under vacuum. To test the water sample, the ampoule tip is broken below the surface of the water sample with a special snapper device supplied with the kit. A vacuum draws the sample into the ampoule where it is mixed. A yellow-orange color develops immediately, allowing an instant comparison of the test sample with liquid color standards supplied in the kit. After mixing, the ampoule must stand for 1 minute and then be read immediately because the color intensifies with time. The presence of TMA offers no interference with the measurement of ammonia by this kit.

The Model AN-10 kit is supplied with two comparators which cover the ranges 0-1 ppm ammonia and 1-10 ppm ammonia. In dogfish flesh the concentration of ammonia will usually be within the range of 0-1,000 ppm or 0-100 mg N per 100 g (mg % N). Therefore, after extraction of the sample, a final hundredfold dilution will provide a sample with an ammonia content within the range suitable for analysis with this kit. The

comparator block contains ten color standards representing ammonia concentrations ranging from 1 to 10 mg % N. In most cases the color intensity of the unknown sample will lie between two adjacent standards and interpolation is required. Thus, a probable range of ammonia concentration will be obtained with the kit rather than an absolute value. However, an estimate of the absolute ammonia concentration can be obtained from the median value of the range. Therefore, if the actual range observed was 0-8 mg % N, the absolute concentration is estimated as 4 mg % N.

Fat Content

Total lipid was obtained by the methanol-chloroform extraction procedure of Bligh and Dyer (1959).

Aerobic Plate Count

Aerobic plate count (APC) was made from appropriate dilutions of the flesh onto pour plates of TPE agar (Standard Methods Agar reinforced with 0.5 percent Bacto-peptone and 0.5 percent NaCl) as recommended by Lee and Pfeiffer (1974) for seafoods. Duplicate plates were incubated at 68°F (20°C) and colony counts were made after 5 days.

The number of urease-positive bacteria was estimated by inoculating half of the colonies from a TPE agar plate containing about 30-100 colonies into individual tubes of Bacto-urea broth. Following an incubation period, if a positive reaction was observed, the number of positive cultures was then multiplied by two and also by the dilution factor of the agar plate from which they were taken to obtain the urease-positive count per gram.

All chemical, physical, or microbial analyses were made on duplicate samples and the average result is reported. Statistical calculations and analyses were performed on a Hewlett-Packard 97 programmable calculator.

Sensory Analysis

For organoleptic evaluation, samples were enclosed in aluminum foil and baked in an oven at 400°F (204°C) for 15-20 minutes for belly flaps, or for 20-30 minutes for fillets. The odor, flavor, and texture of cooked samples were rated on a scale of 9 (excellent) to 1 (inedible) by a six-member taste panel from the scientific laboratory staff. Limit of acceptability was reached when the average sensory rating for either odor, flavor, or texture dropped to a value of 6 (fair). In addition to the usual sensory attributes, panelists were instructed to concentrate on their awareness of ammonia and note its presence when detected.

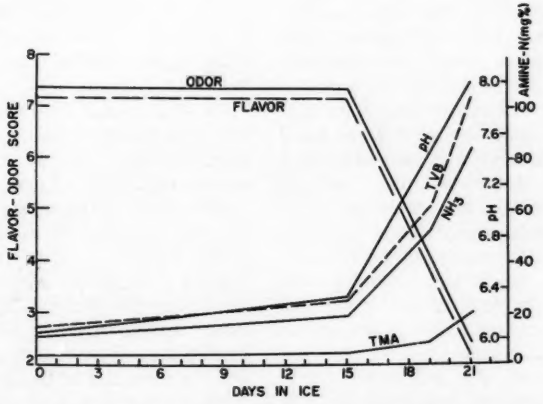

Figure 1.—Storage characteristics of gutted dogfish held in ice.

Results and Discussion

Study 1—Iced Storage Life of Spiny Dogfish

To determine the iced storage life of spiny dogfish, our study was carried out in two parts. The first, using gutted fish, was preliminary, and provided information on spoilage patterns which might be encountered in dogfish and explored the reliability of some chemical and physical tests for quality assessment.

The results of the first part of this study are shown in Figure 1. Flavor and odor of the fillets changed little during the first 15 days of iced storage. Thereafter, quality deteriorated rapidly, and the samples were considered to have lost their shelf life after 16-17 days. Ammonia, TMA, TVB, and pH increased slightly during the first 15 days, but increased markedly thereafter. Thus, the decrease in quality coincided with the increase in volatile amines and pH.

This delayed development of ammonia was unanticipated. Since foreign nations such as Belgium and France concentrate their attention on the ammonia content of imported dogfish, we expected that an early production of ammonia would limit the shelf life. Instead, the ammonia content remained relatively low for the first 2 weeks, and the spoilage pattern seemed not much different from that which develops in iced gadoid fish.

There was a high correlation between ammonia content and either flavor score (r = 0.89) or odor score (r = 0.92). From linear regression analysis, an ammonia concentration of about 32 mg % N was estimated as being indicative of marginal quality dogfish. A high degree of correlation was also observed between flavor score and either pH (r = 0.94), TMA

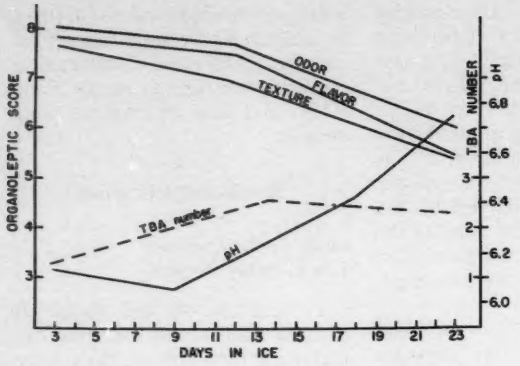

Figure 2.—Storage characteristics of H&G dogfish (fillets) held in ice.

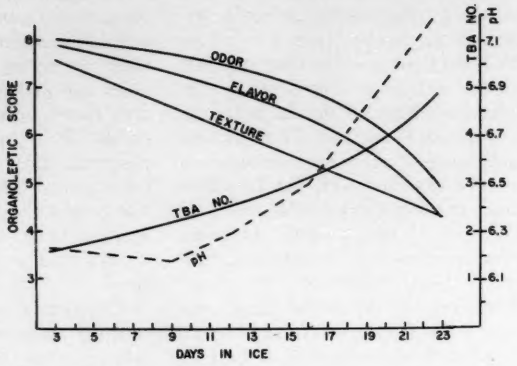

Figure 3.—Storage characteristics of H&G dogfish (belly flaps) held in ice.

content (r = 0.88), or TVB content (r = 0.91). Thus, from these preliminary results it appears that any of these biochemical tests might be useful for assessing spoilage in dogfish providing there is a sufficient degree of accuracy and reproducibility among different batches of fish.

Ammonia content also correlated very well with pH (r = 0.97). Thus, pH measurement also shows potential as a simple, rapid method for monitoring ammonia content.

In the first part of this study attention was focused on icing the fish thoroughly. However, toward the very end of the experiment all the ice beneath the bottom layer of fish had melted and the ventral side of the fish, though still well iced above, was in contact with the wood container. Therefore, Part II of the iced storage study was conducted in December 1980 with H&G fish to ascertain whether the storage life might be extended beyond 16-17 days under conditions which assured complete icing at all times.

In our preliminary study, a few taste test panelists detected rancidity rather than ammonia. And, owing to the dogfish's high fat content (Jhaveri and Constantinides, 1981; Bilinski et al., 1983) we thought it important to include this parameter in our follow-up tests. Because belly flaps have a higher fat content than fillets, the two sections were analyzed separately. We also felt that bacterial testing would be useful, considering the nature of ammonia formation in dogfish.

In Figure 2, the pH value, TBA number, and organoleptic scores for flavor, odor, and texture have been plotted as a function of iced storage time for fillet portions taken from the stored H&G fish. The same parameters are shown in Figure 3 for the belly-flap sections. During storage there was a progressive deterioration in odor, flavor, and texture (softening), and this was accompanied by an increase in pH (due to accumulation of basic amines) and TBA number. Spoilage occurred faster in belly flaps than in fillets. In fact, the fillets were only on the threshold of spoilage after 18 days, whereas the belly flaps were regarded as marginal at about 12-13 days. Rancidity, as measured by TBA number, was more evident in belly flaps; however, a few members of the taste panel reported rancid flavors in the fatty strip along the lateral line of the fillet as early as the 16th day, even though the lean muscle tissue was devoid of rancid flavor throughout the entire storage.

In general, fillet spoilage was due to textural softening and development of ammonia, whereas belly flap spoilage was caused by rancidity, ammonia, and textural breakdown. Thus, from the results of this first study we concluded that the iced shelf life of gutted dogfish, excluding belly flaps, was 16-18 days.

In the scientific literature there is much variation in the estimated storage life for iced dogfish. James and Olley (1971) cited a shelf life for shark (species unidentified) of 10 days at 32°F from a Japanese reference; most important, that shark had been stored in air at 32°F and not in melting ice at 32°F. Southcott et al. (1960) reported that less ammonia and TMA were produced in dogfish stored in ice than when stored in air at 32°F. Therefore, this implies that the iced storage life of the shark referred to by James and Olley (1971) would be greater than 10 days.

An iced storage life of 16-19 days was determined by Southcott et al. (1960) for H&G dogfish. The species was reported as Pacific coast dogfish, *Squalus suckleyi* (since established as the same species as the Atlantic coast spiny dogfish, *Squalus acanthias*). Stansby et al. (1968) concluded that the storage life of iced H&G Pacific coast dogfish was limited to the development of rancidity and shelf life was estimated as 14 days. In our study, storage lives were determined separately for the belly flap and fillet section with flap removed; we con-

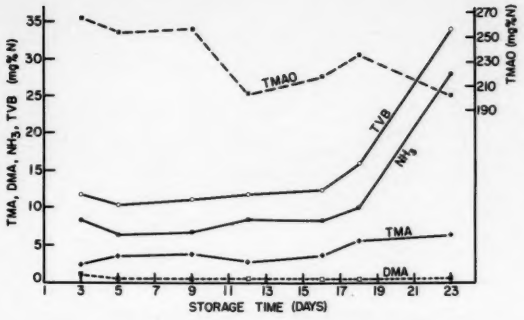

Figure 4. – Effect of storage time at 32°F (0°C) on the content of certain volatile amines in H&G dogfish (fillet portion).

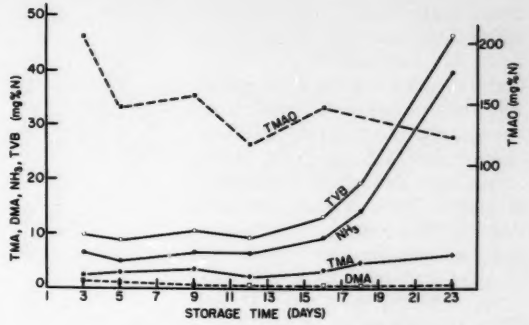

Figure 5. – Effect of storage time at 32°F (0°C) on the content of certain volatile amines in H&G dogfish (belly flaps).

ceded that rancidity was probably a significant factor involved in belly flap spoilage but not of the flapless fillet. Stansby et al. (1968) may have been testing the entire fillet with belly flap attached. Even so, from the cited shelf lives it would appear that the iced shelf life of H&G dogfish would be comparable to that for cod and haddock.

Most recently Bilinski et al. (1983) found no significant increase in ammonia during 20 days of storage of iced gutted dogfish; however, quality loss during iced storage was detected earlier due to the development of off odors and off flavors, softening of the flesh, and autolysis of the abdominal walls. They concluded that these changes limited the useful iced storage time to 8-10 days.

The shortest life reported for iced H&G dogfish was 7 days, based on ammonia detection at that time (Jhaveri and Consantinides, 1981). In our study, the ammonia content (and TVB) were relatively stable during the first 16 days of storage, but increased thereafter (Fig. 4, 5). Stansby et al. (1968) similarly found that the TVB was low (< 12 mg % N) during the first 14 days of storage of iced dogfish. Moyer et al. (1959) reported that the TVB remained at a level of about 10 mg % N throughout the first 12 days of iced dogfish storage, and after 3 weeks had only increased to 18 mg % N with no ammonia detected by sensory analysis.

Elliot (1952) also noted a slight trace of ammonia after just 6 days in the minced dogfish stored in jars at 32°F. However, minced fish is certainly more prone to microbial degradation than intact muscle because of the increased surface area, rupture of cells releasing enzymes, nutrients, etc., and dogfish spoils faster in air at 32°F than in ice at 32°F. Therefore, these factors could account for the early ammonia production observed by Elliot (1952). Also, Elliot's generally high values of ammonia are likely due in part to his method of analysis which utilized dogfish muscle extracts without the removal of protein.

Vyncke (1968) reported slight increases in ammonia in dogfish during only the first 8 days of storage in ice and a rapid increase after that period to reach values of 75 mg % N flesh after 14 days. His analyses were carried out on protein-free extracts; however, the postmortem age of his samples was not indicated. In another study, Vyncke (1970) used 5-day postmortem fish with an initial TVB concentration of 30 mg % N and reported a slow rise to about 35 mg % N until 9 days postmortem, a sharper rise to about 55 mg % N until 12 days postmortem, and finally a very rapid increase to more than 90 mg % N until 15 days postmortem. Ammonia accounts for the major portion of the TVB production since, as Elliot (1952) reported, the high concentrations of trimethylamine occurring in dogfish flesh and other elasmobranchs are reduced only in small amounts to trimethylamine. The results of our study are most compatible with those of Moyer et al. (1959) and Stansby et al. (1968).

In the second part of our study an ammonia content of about 20 mg % N was predicted at the estimated spoilage time. A value of about 30 was noted in the first part of this study. These spoilage levels are much less than the value of 60 mg % N recommended by Vyncke (1968) as the cutoff value for acceptable/unacceptable imported dogfish.

DMA concentration remained relatively constant and insignificant (< 1 mg % N) throughout storage of both fillets and belly flaps (Fig. 4, 5). Hence our results indicate that a spoilage test based on DMA content would not reliably measure quality of iced dogfish.

The TMA content increased gradually over the 23-day storage period, attaining a final maximum value of about 6 mg % N. Usually at spoilage, at least for cod, a TMA con-

centration of about 15 mg % N is obtained (Dyer and Dyer, 1949). In their study with iced dogfish, Moyer et al. (1959) reported that the TMA content was low throughout 21 days of iced storage, and had only reached a maximum value of 5 mg % N. Similar results were obtained by Southcott et al. (1960). These investigators found that the TMA content of iced dogfish remained constant for about the first 14 days and reached an estimated value of 10 mg % N after 20 days. Elliot (1952) likewise encountered a relatively low final TMA concentration in his studies with minced dogfish muscle stored at 32°F.

Trimethylamine is formed by the action of a bacterial enzyme, triamine oxidase, on the precursor substance, trimethylamine oxide (TMAO), found in marine species. The optimum pH for activity of this enzyme was reported to be 7.2-7.4 in cod (Castell and Snow, 1949). This optimum range was also confirmed in dogfish by Elliot (1952), who speculated that the reason for only a small amount of TMA produced in dogfish (compared with gadoid species) during spoilage is that the urease-positive bacteria become active sooner than the TMA-producing bacteria, thus forming ammonia which soon elevates the pH beyond the optimum for triamine oxidase activity.

More TMAO was degraded (reduced) than could be accounted for by the production of end products such as TMA or DMA. For example, the TMAO content of fillets decreased by about 58 mg % N over the 23-day period, yet TMA only reached a maximum value of about 6 mg % N. Dyer et al. (1946) studied iced gutted cod and observed a disappearance of TMAO which they attributed to leaching by the melting ice. There was a higher initial concentration of TMAO in the fillet portion (263 mg % N compared with the belly flaps, 204 mg % N), and this could be related to the compositional differences between these two anatomical sections.

Among sharks, dogfish must have a unique fat content. Sidwell et al. (1974) reported a fat content of 0.5 ± 0.2 percent for mixed shark species. And in 19 out of 21 shark species compared, the fat content was less than 2 percent (Gordievskaya, 1971). The two exceptions were sevengill shark (13 percent fat) and Greenland shark (10 percent fat).

We found the dogfish fat content (mean ± 1 S.D.) averaged 11.2 ± 2.2 percent for fillets and 22.6 ± 3.7 percent for belly flaps. A seasonal variation was reported in the lipid content of dogfish with a mean value and standard deviation of 14.5 ± 2.2 percent, and highest fat content occurring during the winter months (Jhaveri and Constantinides, 1981). However, these researchers analyzed a composite sample taken from dorsal and ventral areas, and therefore our results cannot be compared directly with theirs.

Bilinski et al. (1983) reported a muscle fat content of 16.51 percent, SE = 0.62. Again, our direct comparison with their results is impossible because their determinations were made on homogenates of three steaks (25 mm thick and devoid of skin and bone) cut from the head, middle, and tail regions of each fish and containing both the dorsal and the belly portion of the muscle.

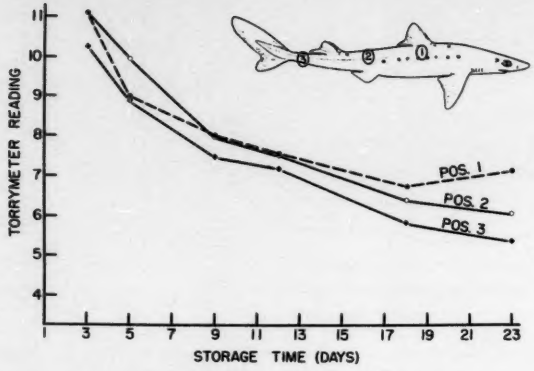

Figure 6.—Effect of storage time at 32°F (0°C) on Torrymeter readings taken at three different positions on dogfish.

Thus, while all sharks are subject to spoilage from ammonia formation, a few species—including dogfish—are additionally susceptible to rancidity because of their high fat content.

Moisture content of 24 spiny dogfish caught in September 1981 ranged between 67.96 and 76.20 percent, with an average moisture content and standard deviation of 71.56 ± 1.94 percent. For 21 fish caught in December 1981, fillets and belly flaps were analyzed separately. Moisture content of the fillets ranged between 67.68 and 74.65 percent, with an average moisture content and standard deviation of 71.35 ± 1.99 percent; the belly flaps ranged between 60.0-68.70 percent with an average moisture content and S.D. of 64.55 ± 2.35 percent. Very good correlation (r = 0.93) was observed between fat content and moisture content. The regression equation was $Y = 114.7 - 1.45X$. Thus, a quick estimate of the fat content of dogfish muscle could probably be obtained using a rapid moisture determination method.

Quality loss during iced storage was also monitored with the Torrymeter. Readings were taken at three consecutive positions along the lateral line (Fig. 6) between the first dorsal fin and the caudal peduncle. Readings were generally constant in the region

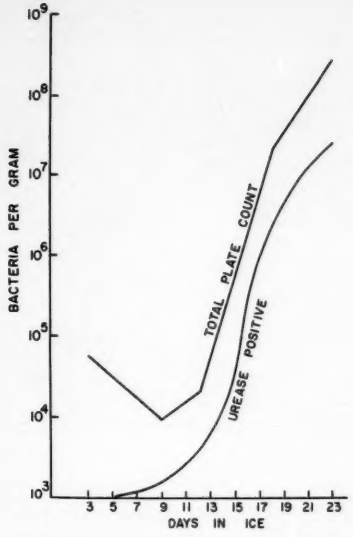

Figure 7.—Bacterial content (total plate count or urease-positive bacteria) of H&G dogfish held on ice.

between the two dorsal fins, but were lower at the caudal peduncle. The average Torrymeter readings taken at the three different positions are plotted in Figure 6 as a function of storage time.

The readings dropped steadily from an initial (3 days postmortem) average reading of 11 to a final reading of about 6-7 at the end of shelf life. A Torreymeter reading of about 6-7 is the usual value we have observed in previous studies of marginal quality fish with cod and haddock. Thus, the Torrymeter could have possible application for measuring quality of iced dogfish if the limitations of the instrument are understood and if the instrument is consistent from one lot of fish to another.

Postmortem ammonia in most fish arises from the enzymatic deamination of proteins, amino acids, and some other basic nitrogen compounds in the flesh. However, in elasmobranchs, which have an unusually high level of urea in the flesh and blood, most postmortem ammonia is formed by enzymatic degradation of urea. Shewan (1951) reported such levels up to 2 percent in dogfish muscle. The enzyme responsible for this activity is urease which is present in certain microorganisms. During our 23-day iced-storage study, the total number of aerobic bacteria (APC) and the numbers of microorganisms capable of splitting urea into ammonia (urease-positive) were monitored. The APC decreased slightly during the first 12 days, then rose sharply during the following 11 days to a final average count of about 300 million per gram (Fig. 7). Moyer et al. (1959) reported an APC of about 74 million per gram at the time iced dogfish was considered of marginal quality.

In our study, the APC at the threshold of spoilage was estimated as 15 million per gram. Throughout storage, the percentage of urease positive bacteria remained relatively constant, ranging from 3 to 20 percent of the total microbial population; however, as the total bacterial count increased, so did the number of urease-positive bacteria which at spoilage was estimated at 2 million per gram. Southcott et al. (1960) monitored the APC and urease-positive bacterial count of iced H&G dogfish, concluding that an obligate urea-utilizing population was not established to the exclusion of other types. Our result is consistent with their conclusion.

Table 1.—Regression data for flavor score of either dogfish fillets or belly flaps as a function of various spoilage indicators.

Item	Regression	Correlation coefficient	Intercept	Slope	n
Fillet	Flavor score vs. TBA number	0.42	8.15	−0.54	21
Belly flap		0.77	8.79	−0.79	20
Fillet	Flavor score vs. TMA content	0.77	8.61	−0.43	21
Belly flap		0.84	9.34	−0.75	21
Fillet	Flavor score vs. ammonia content	0.79	8.01	−0.09	21
Belly flap		0.91	7.75	−0.09	21
Fillet	Flavor score vs. TVB content	0.81	8.22	−0.08	21
Belly flap		0.91	8.01	−0.08	21
Fillet	Flavor score vs. pH	0.84	24.46	−2.77	21
Belly flap		0.92	26.94	−3.14	21
Fillet	Flavor score vs. log APC	0.93	9.72	−0.49	21
Belly flap		0.98	9.82	−0.48	21
Fillet	Ammonia content vs. pH	0.84	−143.4	24.57	21
Belly flap		0.90	−206.4	33.87	16
Fillet	Flavor score vs. Torrymeter reading	0.76	3.89	0.39	

Linear regression data for flavor score of either fillets or belly flaps are presented as a function of various chemical or physical spoilage indicators for fish in Table 1. In general there was good correlation between flavor score with either TBA number, TMA, ammonia, TVB, pH, Torrymeter reading, and (log) APC. The only exception was the low correlation between flavor score of fillets and TBA number. Fillet spoilage was more associated with bacterial activity than with lipid oxidation. Although some of these chemical/physical parameters correlated well with flavor score, they would only be useful as spoilage indicators and not freshness indicators.

The ammonia nitrogen content at spoilage was estimated from the regression equation to be 20-23 mg % N. This is well below the specified limit for acceptable exported dogfish and corroborates the results of the first part of this study.

There also was good correlation between ammonia content and pH, which confirms the results of the first part of this study; however, the regression lines computed from the two parts of this study $Y = 33.9X - 194.1$ (Part I) and $Y = 24.6X - 143.4$ (Part II) were sufficiently diverse as to render this predictive parameter (pH) questionable at this time.

Flavor score correlated well with pH ($r = 0.89$) and the relationship is

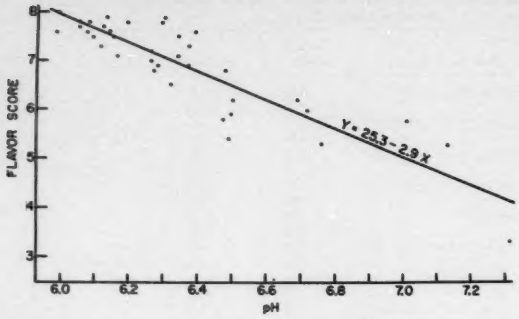

Figure 8.—Flavor score of iced H&G dogfish as a function of pH.

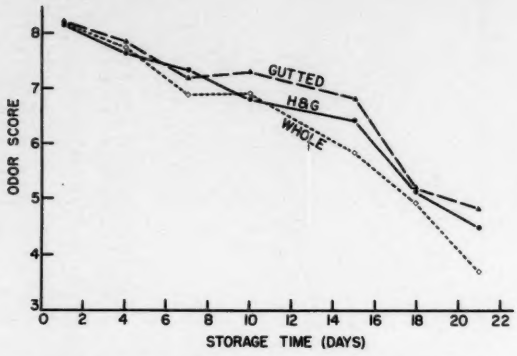

Figure 9.—Effect of storage time on the odor score of cooked fillets cut from dogfish dressed in various ways and held in ice.

shown in Figure 8. Although the degree of scatter of the data points precludes the use of pH for accurately assessing flavor score, this parameter might possibly be employed as a rapid screening method to delineate acceptable from nonacceptable fish by establishing some arbitrary pH, such as pH 6.7, as the cutoff value. A rapid measurement on a fresh fillet or skinned fish could be made with a surface electrode.

Study 2—Effect of Gutting, and Heading and Gutting

This study was made to determine the effect of heading and gutting, gutting alone, and bleeding on the quality of dogfish during storage in ice. Dogfish blood contains a high amount of urea, which decomposes to ammonia, as well as a high concentration of TMAO, the precursor of TMA, a compound absent from the blood of teleosts (Benoit and Norris, 1945). Viscera are also a source for spoilage, particularly when the fish have been feeding, and the products of bacterial metabolism can diffuse through the stomach and intestinal walls and permeate the flesh. Therefore, it is important to determine the role of these potential spoilage factors on the shelf life of iced dogfish.

Bleeding is recommended to preserve flavor and prevent darkening of the flesh due to oxidation of the blood pigments hemoglobin and myoglobin. However, in the European market a red color of the flesh is considered an indicator of high quality in fresh dogfish. Therefore, bleeding the fish would appear to be counterproductive since this treatment would tend to produce a white or light-colored flesh.

During the first 10 days of iced storage there was not much difference in the odor score of cooked fillets cut from fish stored in one of the three different ways. Beyond that time the whole fish (fillets) were scored slightly lower than the fillets from either gutted or H&G fish which were rated about the same (Fig. 9). The graphs of flavor score as a function of storage time followed a similar pattern (Fig. 10). On the 15th day some panelists reported a slight rancid flavor in the fillets from the gutted fish and a slight flavor of decomposition in fillets from the whole fish. No ammonia flavor was detected at this time but after 18 days some comments on an ammonia flavor were noted. After 21 days all samples were rancid and, in addition, fillets from the whole fish had a strong decomposed odor/flavor. The odor of rancidity and putrefaction overpowered any ammonia present. Texture scores during storage have been plotted in Figure 11 for the three treatments. No textural differences were observed during about the first 8 days but beyond that the whole fish (fillets) appeared to be rated slightly lower compared with the other two treatments owing to a softer texture. The approximate storage times at which the fish were considered to be of marginal quality due to either an unacceptable odor, flavor, or texture were determined by linear regression to be as follows:

Storage method	Iced shelf life (days)		
	Odor	Flavor	Texture
Whole	14.0	11.5	13.0
Gutted	16.5	16.0	17.0
H&G	16.0	16.0	15.0

Thus, it appears that flavor deterioration or off-flavor development was the limiting factor for product acceptability. The advantage of gutting in extending the shelf life is also apparent.

Prolonged storage of spiny dogfish in the round could seriously diminish the shelf life if the belly flaps were to be utilized. After 4 days of iced storage, an undesirable yellow-green discoloration was observed on the belly flaps of some of the whole fish. We believe that contact with certain visceral organs was responsible for this.

Moisture content did not change significantly throughout the 24-day iced-storage period although there was some variability among in-

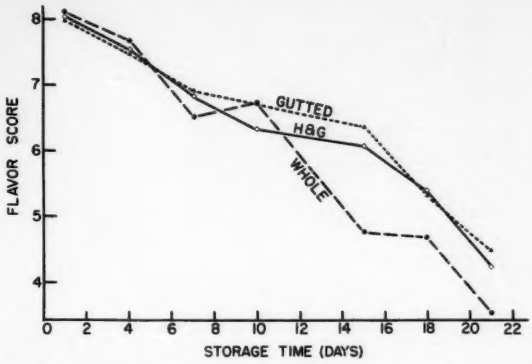

Figure 10.—Effect of storage time on the flavor score of cooked fillets cut from dogfish dressed in various ways and held in ice.

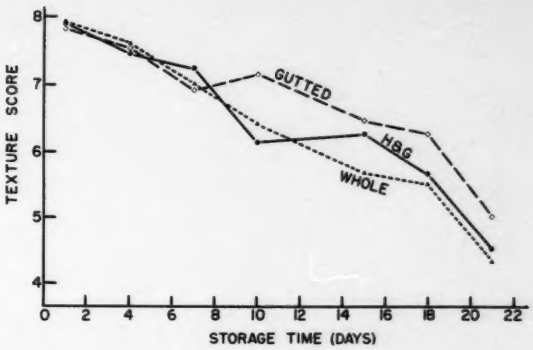

Figure 11.—Effect of storage time on the texture score of cooked fillets cut from dogfish dressed in various ways and held in ice.

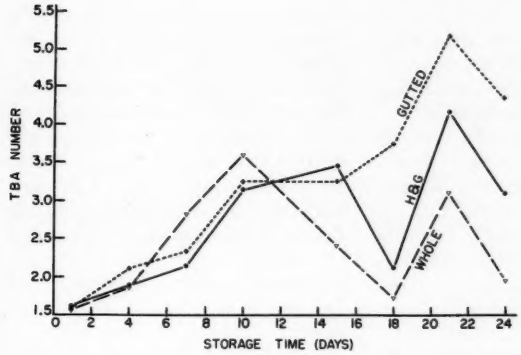

Figure 12.—Effect of storage time on TBA number of fillets cut from dogfish dressed in various ways and held in ice.

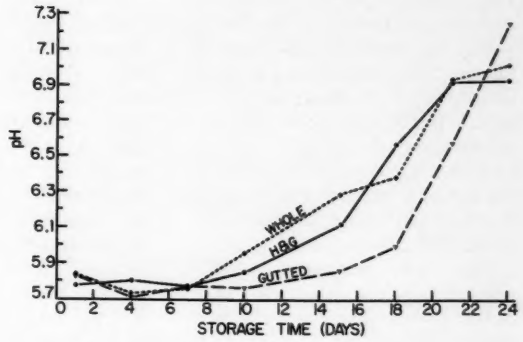

Figure 13.—Effect of storage time on the pH of fillets cut from dogfish dressed in various ways and held in ice.

dividual fish. Based on 16 fish per treatment, the average moisture content (±1 S.D.) for the three treatments during storage was: Whole, 70.9 ± 3.0; gutted, 69.7 ± 1.9; and H&G, 69.7 ± 2.0.

Dogfish stored whole had about a 1 percent higher moisture content compared with gutted fish. However, this slightly higher moisture content was not associated with the slightly softer texture of the whole fish since correlation between texture score and moisture content was found to be low. Enzymes in the gut were probably responsible for the softer texture of the whole fish.

The development of oxidative rancidity (indicated by TBA number) is shown for the three different storage treatments in Figure 12. From the general trend of the data points, it appears that over the 24-day storage period rancidity developed to a greater degree in the gutted or H&G fish than in the whole fish. This is reasonable since gutting the fish exposes the visceral cavity to air which is responsible for oxidation. Stansby et al. (1968) and Bilinski et al. (1983) also reported less rancidity (based on peroxide value) in the oil extracted from iced dogfish stored in the round compared with H&G or gutted dogfish. The rate of increase in TBA number per day (mg malonaldehyde/kg/day) was determined to be 0.14 for gutted fish, 0.08 for H&G fish, and 0.01 for whole fish. The pH remained relatively constant during the first 10 days and began to increase thereafter, fastest in the whole fish and slowest in the gutted fish (Fig. 13).

Trimethylamine nitrogen content remained relatively stable at an average value of about 3 mg % N for all treatments over 18 days and then started to rise. This agrees with the results of Bilinski et al. (1983) who found that TMA contents of whole, bled, or gutted dogfish did not exceed

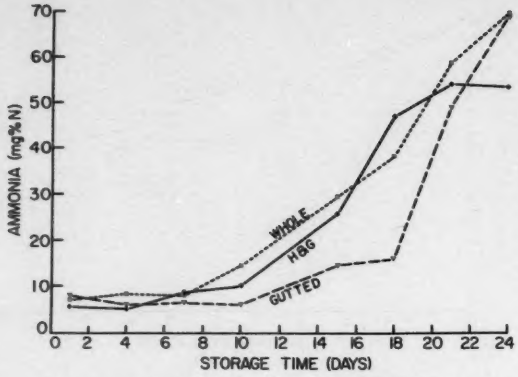

Figure 14.—Effect of storage time on ammonia nitrogen content of dogfish (fillets) dressed in various ways and held in ice.

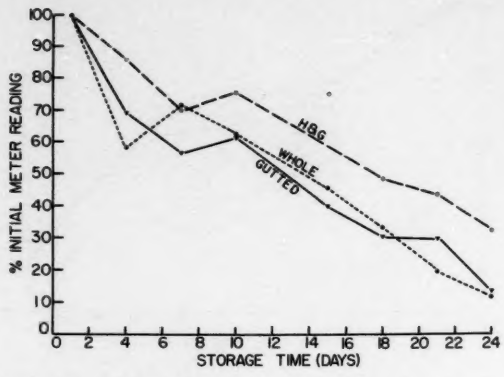

Figure 15.—Effect of storage time on the percent change in Torrymeter reading taken on dogfish dressed in various ways and held in ice.

1 mg % N during storage on ice for 15 days. Only afterward did the TMA of whole fish show a slight increase, though by 20 days it still remained under 3 mg % N. However, after 18 days, our fish were either spoiled or on the verge of spoilage. Therefore, we concluded that TMA production did not play a major role in quality deterioration other than contributing to the TVB content.

There was no change in DMA nitrogen content over the entire 24-day storage period for any treatment. The average contents (and S.D.) were as follows: Whole fish, 0.30 mg % N (0.16); gutted fish, 0.23 mg % N (0.11); H&G fish, 0.22 mg % N (0.10). There was no significant difference between these average values and we concluded that DMA content did not affect the spoilage process.

Over the 24-day storage, the TMAO-N content decreased linearly from an average initial value for the three treatments of 275 mg % N to a final average value of 100 mg % N. The rate of TMAO-N decrease was 9.5 mg % N per day for whole fish compared with 5.8 mg % N per day for gutted fish or 5.3 mg % N per day for H&G fish. During this period we found only about 6-7 mg % N from TMA formed in any of the fish. From these data it is difficult to attribute the unaccountable decline in TMAO content to leaching from melting ice, as has been suggested, since there was a greater rate of loss in whole fish compared with gutted fish which had more leachable surface exposed.

Ammonia content remained unchanged for about the first 10 days of storage and then began to increase, most rapidly in the whole fish and least rapidly in the gutted fish (Fig. 14). Bilinski et al. (1983) found little increase in ammonia in any of the whole, gutted, or bled dogfish during the first 11-12 days of storage on ice; hence, little difference between the treatments. After 14 days a slightly greater concentration of ammonia was apparent in the unbled fish than in those bled, whereas after 20 days there was considerably more ammonia in the iced/ungutted fish ($\approx$ 67 mg % N) than in the gutted fish ($\approx$ 13 mg % N fish). The amount of ammonia found in our iced and gutted samples far exceeded the amount found by Bilinski et al. (1983), and after 20 days was only slightly less than in the iced/ungutted fish. Unfortunately, those investigators did not continue their bled vs. unbled study beyond 14 days during the period of greater ammonia production. Even so, an exact comparison of our results would not have been possible since our methods of bleeding differed.

The course of ammonia production for the three different treatments seemed to coincide with pH change. The estimated time at which the ammonia nitrogen content reached a value of 55 mg % N—the limit mandated by Belgium for acceptability—was 20-22 days; yet, the taste panel regarded the useful storage life to have terminated after 11-16 days because of quality deterioration other than an objectionable ammonia content.

The accumulation of TVB followed the same general pattern as ammonia production. This was expected since, as stated, TVB is predominantly ammonia. In the industry, a value of 30 mg % N for TBV is considered to be indicative of spoilage in fish (Farber, 1965). This value is within the range we found at the end of dogfish shelf life.

The percent decrease in Torrymeter reading during storage is shown in Figure 15. These percentages were computed by comparing the reading at a particular storage time with the reading initially recorded for that tagged fish. The highest readings, indicative of best quality, were consistently obtained with H&G fish. The rates of percent decrease in Torrymeter reading per day were determined for the different treatments by linear regression to be: Whole fish, 3.3; gutted fish, 3.1; H&G fish, 2.7.

The average initial reading based on 48 fish was 11.3 ($\pm$1.5 S.D.). By

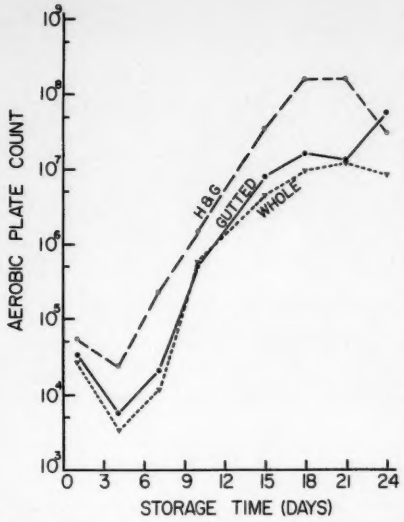

Figure 16.—Effect of storage time on the bacterial content of fillets cut from dogfish dressed in various ways and held in ice.

Table 2.—Regression data for flavor score of dogfish fillets as a function of various spoilage indicators.

Treatment	Regression	Correlation coefficient	Intercept	Slope	n
H&G	Flavor score vs. ammonia content	0.92	7.62	−0.06	14
Gutted		0.85	7.61	−0.07	14
Whole		0.84	7.58	−0.06	14
H&G	Flavor score vs. TMA content	0.64	8.50	−0.55	14
Gutted		0.33	7.76	−0.35	14
Whole		0.10	6.71	−0.19	14
H&G	Flavor score vs. TVB content	0.92	7.79	−0.05	14
Gutted		0.82	7.76	−0.06	14
Whole		0.79	7.76	−0.06	14
H&G	Flavor score vs. TBA number	0.69	8.71	−0.88	14
Gutted		0.81	8.81	−0.74	14
Whole		0.22	7.08	−0.40	14
H&G	Flavor score vs. pH	0.89	21.44	−2.46	14
Gutted		0.77	23.92	−2.93	14
Whole		0.79	20.44	−2.33	14
H&G	Flavor score vs. log APC	0.91	10.92	−0.71	12
Gutted		0.81	10.39	−0.70	12
Whole		0.84	10.78	−0.92	12
H&G	Flavor score vs. Torrymeter reading	0.88	2.91	−0.43	14
Gutted		0.77	4.73	−0.30	14
Whole		0.86	0.42	−0.42	14
H&G	Ammonia content vs. pH	0.97	−234.3	41.91	16
Gutted		0.96	−238.7	42.78	16
Whole		0.96	−219.3	39.57	16
H&G	Texture score vs. moisture content	0.28	17.83	−0.16	14
Gutted		0.02	5.99	0.01	14
Whole		0.41	10.03	−0.18	14

linear regression analysis we determined that at spoilage, the Torrymeter reading had decreased to 40-55 percent of the initial value. This would indicate a meter reading at end of shelf life of 5-6 which is comparable to the reading of 6 that was determined in our previous study.

Bacterial content (APC) during storage in ice is plotted in Figure 16. The APC at any time was greatest in H&G fish and least in the whole fish. The flesh of freshly caught fish is sterile, but bacteria are on the skin, gills, and in the intestines. When fish are gutted, the visceral cavity is exposed to contamination, particularly if the fish have not been properly gutted. Improper gutting, (i.e., rupture of intestines or stomach) can cause heavy bacterial contamination of the gut cavity which can shorten the shelf life of gutted fish. Bacteria in the belly cavity of gutted fish will have access to more air than bacteria growing in the belly cavity of ungutted fish, and may proliferate at a faster rate. Bacteria growing where air is restricted, as in the digestive organs of whole fish, may alter their metabolism (become anaerobic) and produce malodorous compounds (i.e., hydrogen sulfide) typical of "bilgy" fish (McLean and Castell, 1956). The tough hide of dogfish would seem to provide a good barrier against bacterial penetration; therefore, bacterial invasion of the flesh probably originates inside the belly wall.

Removing the head creates another cut surface for potential bacterial contamination and a foci for invasion of tissues such as through the vascular system. By not eviscerating, intestinal bacteria are contained within that system and do not invade the flesh; however, as stated, bacterial growth within the intestines will eventually produce undesirable end products which may diffuse through the intestinal wall, permeate the flesh, and cause spoilage even though the flesh may contain a relatively low bacteria count. This appears to be the scene depicted by the curves in Figure 16.

Regression data for flavor scores and other parameters as a function of various spoilage indicator tests are given in Table 2. There was good correlation between flavor scores and either ammonia content, TVB, pH, bacterial content, or Torrymeter reading. Flavor scores correlated fairly well with TBA number in gutted or H&G fish, but poorly in whole fish. There also was a low correlation between flavor scores and TMA content. The following spoilage criteria, predicted by the regression lines for the various parameters, signalled the end of useful shelf life.

Ammonia N content	24-29 mg%N
TVB	28-34 mg%N
pH	6.2-6.3
Torrymeter reading	5-7
TBA number	3-3.8

There was a high degree of correlation between ammonia content and pH. The regression value for pH corresponding to an ammonia nitrogen content of 55 mg % N was about 6.9.

These results seem to indicate that there would be some advantage to the immediate gutting of fish, especially if high-quality belly flaps are desired. However, if fishing trips are short (1-2 days), the fishermen's time would be best spent on chilling the fish as quickly as possible and keeping them well-iced until processed.

Study 3—Effect of Storage Temperature

This study was made to determine the effects of temperature abuse on dogfish quality from mishandling, either aboard the fishing vessel or in the processing plant. During storage,

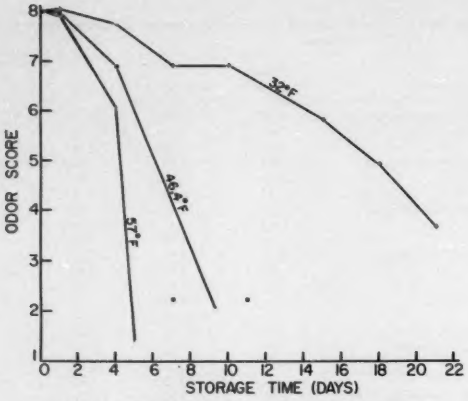

Figure 17.—Effect of storage time on odor score of cooked fillets from dogfish stored whole at various temperatures.

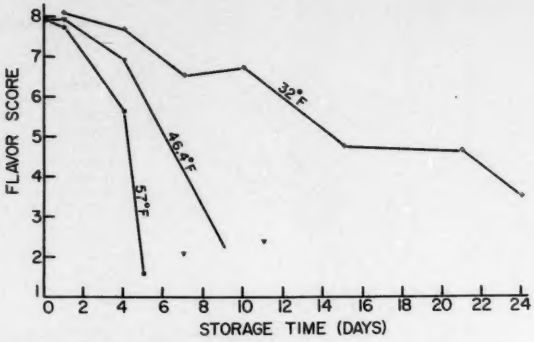

Figure 18.—Effect of storage time on flavor score of fillets from dogfish stored whole at various temperatures.

the rate of decrease in odor, flavor, and texture on scores of fillets removed from whole fish was commensurate with the storage temperature (Fig. 17, 18, 19). During the first 2 days of storage, quality differences due to temperature were not as great as anticipated. After the first day a slight bitter flavor was detected in fillets from fish held at either 46.4° or 57°F (8° or 14°C), but no ammonia or decomposition odors were noted. We believe that off-flavor may have reflected the initial stages of oxidative rancidity. After 4 days some stale flavor was noted, and ammonia was slightly detectable in the cooked samples; however, a strong ammonia odor prevailed after 5 days at 57°F (14°C) or after 7 days at 46.4°F (8°C). Shelf life, from the curves in Figures 17, 18, and 19, was estimated as follows:

Storage temperature	Shelf life (days) based on: Odor	Flavor	Texture
32°F (ice 0°C)	14	12	13
46.4°F (8°C)	5	5	5
57°F (14°C)	4	3.5	4

As in Study 2, flavor change was the most important sensory factor governing shelf life. These shelf lives are somewhat longer than others (Anonymous, 1981) reported: 6, 3.5, 2, and 1.5 days at 5, 10, 15, and 20°C (41, 50, 59, and 68°F), respectively. Vyncke (1967) reported ammonia concentrations of about 70 mg % N in skinned and headed dogfish held 2 days at 20°C (68°F) and in others held 5 days at 15°C (59°F). Ammonia in the fish held at 15°C (59°F) reached about 37 mg % N after 2 days. All those studies were begun 5 days postmortem with ammonia concentrations of about 26 mg % N.

One might reason beforehand that at the two elevated storage temperatures the fish would lose some moisture which could affect texture. During the latter part of our storage period, the fish held at either 46.4°F (8°C) or 57°F (14°C) did have a dry skin and a slightly shrivelled appearance, but the flesh moisture content did not decrease. Thus, dogfish skin appears to be a good protector of flesh moisture.

In Figure 20, shelf life (days) based on flavor deterioration has been plotted as a function of storage temperature over a range from 32° to 57°F (0°-14°C). The relationship appears to be a first order reaction. The sharp slope change over the 32°-46°F (0°-14°C) span compared with the 46°-57°F (8°-14°C) span shows why the product should be stored as close to 32°F (0°C) as possible. The reciprocals of these shelf lives were considered to represent the spoilage rates for the reaction at the corresponding temperatures, and from these data an Arrhenius plot was constructed (Fig. 21). From the slope b of the regression line, the activation energy, E_A, for the reaction was determined:

$$\text{Slope } b = \frac{-E_A}{(2.303)(R)},$$

where R = molar gas constant,
= 1.987.

The activation energy was computed to be 14,700 cal/mole and this is in accord with the activation energy values of 15,000-18,000 cal/mole reported by Torry Research Station scientists for various spoilage tests on wet fish at temperatures from 34° to 59°F (1°-15°C) (cited by James and Olley, 1971). A slightly higher activation energy of 17,000 cal/mole was calculated by James and Olley (1971) for spoilage of uniced shark (species not named) based on the time required for the ammonia nitrogen content to reach 30 mg % N. Their raw data were taken from various published studies—perhaps even from studies on mixed shark species. In general, the spoilage times cited by James and Olley (1971) were lower by a factor of about 0.75 than ours.

There was no significant increase in TBA number at any of the storage temperatures to signify a major development of oxidative rancidity. In Study 2 rancidity was not a problem in iced whole fish, and Study 3 in-

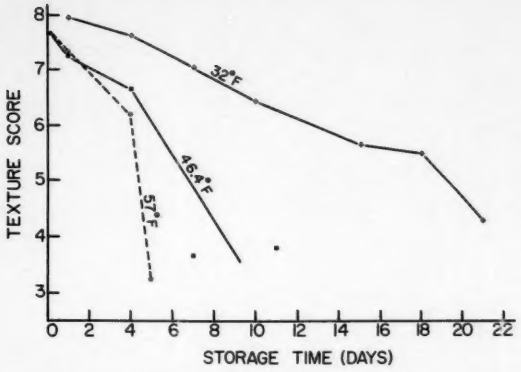

Figure 19.—Effect of storage time on texture score of fillets from dogfish stored whole at various temperatures.

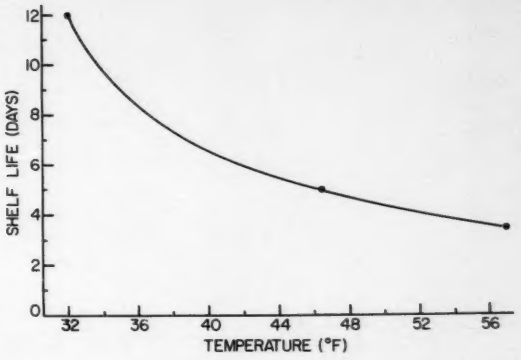

Figure 20.—Shelf life of whole dogfish as a function of storage temperature.

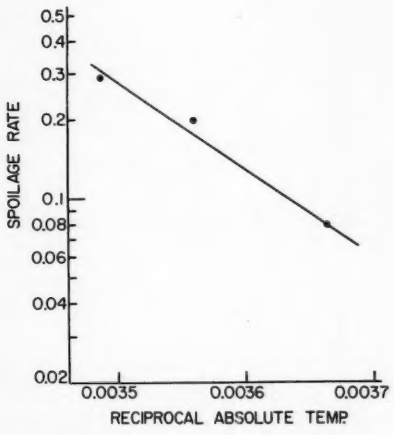

Figure 21.—Spoilage rate of whole dogfish as a function of temperature.

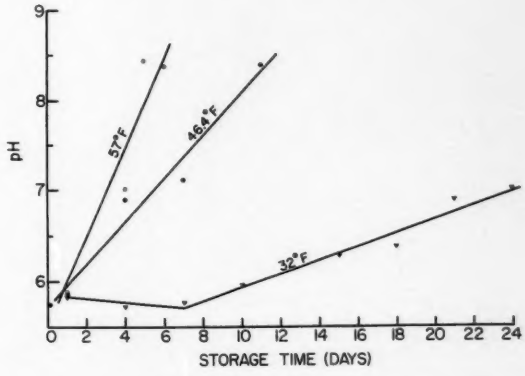

Figure 22.—Effect of storage time on pH of fillets from dogfish stored whole at various temperatures.

dicates no serious problem even at temperatures up to 57°F (14°C) although some rancidity did eventually develop. Bilinski et al. (1983) also reported low TBA values in dogfish stored at elevated temperatures, 41° and 50°F (5° and 10°C).

The rate of increase in pH during storage was also temperature dependent (Fig. 22). The initial pH of the fish in both Studies 2 and 3 was about 5.8. The ultimate pH for most teleosts at the end of rigor has been stated to be 6.2-6.5. Gordievskaya (1971) reported that, compared with other fish, shark meat is rather acidic. One would expect this acidic nature of dogfish flesh to enhance its shelf life.

The effect of storage temperature on production of the basic volatile amines—ammonia, TMA, DMA—is shown in Figures 23, 24, and 25. While in the previous studies we found no significant increase in TMA or DMA during dogfish storage on ice, we found a substantial increase in these amine compounds during uniced storage at 46.4°F or 57°F (8°C or 14°C) similar to that reported by Bilinski et al. (1983) at 41° and 50°F (5° and 10°C). Since these amines are produced as a result of microbial activity, one would expect the bacterial growth to reflect a similar temperature dependency. That they did can be seen in Figure 26; however, there is a notable lag in bacterial increase during the first 8 days at 32°F (0°C) which contributed to the extended shelf life at this lower temperature.

The decrease in dogfish Torrymeter readings during storage is shown in

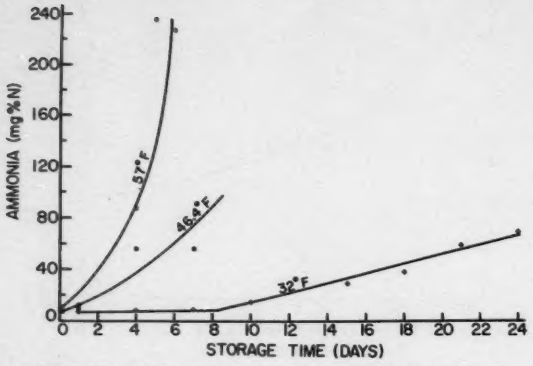

Figure 23.—Effect of storage time on ammonia nitrogen content of fillets from dogfish stored whole at various temperatures.

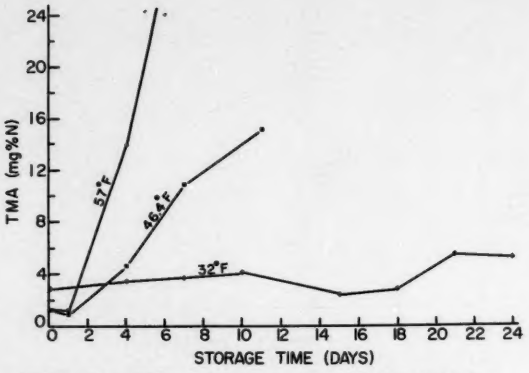

Figure 24.—Effect of storage time on trimethylamine nitrogen content of fillets from dogfish stored whole at various temperatures.

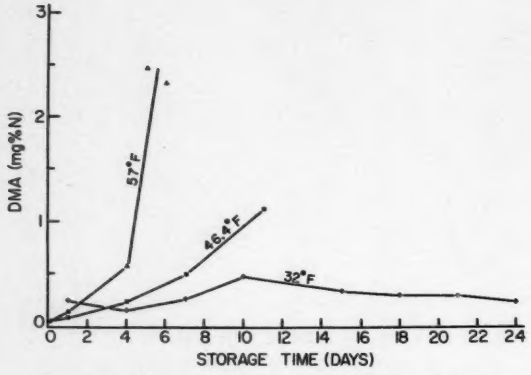

Figure 25.—Effect of storage time on dimethylamine nitrogen content of fillets from dogfish stored whole at various temperatures.

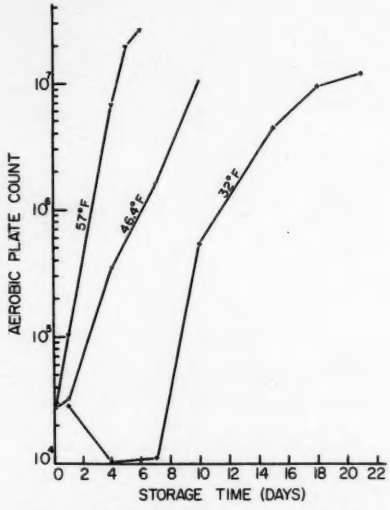

Figure 26.—Bacterial content of dogfish stored whole at various temperatures.

Figure 27. By interpolation we determined that a meter reading of 4-6 would indicate the end of shelf life, based on shelf lives of 12 days at 32°F (0°C), 5 days at 46.4°F (8°C), and 3.5 days at 57°F (14°C), as estimated from sensory evaluation. During storage at the two higher temperatures, the skin began to dry and the Torrymeter would not register a readout unless the skin was slightly moistened.

Rates of TMA, DMA, ammonia production, and bacterial growth are plotted as a function of temperature in Figure 28. These rates are the regression slopes of the curves shown in Figures 24-27, and illustrate the rapid increase in rate of either bacterial growth or volatile amine production at storage temperatures above about 50°F (10°C). Therefore, it behooves the fisherman or processor to maintain low storage temperatures for dogfish to retard the production of the volatile amines and other bacterial decomposition products strongly associated with spoilage. Thus, with proper iced storage, dogfish can have keeping quality comparable to similarly stored cod and haddock.

Some regression data for flavor scores of dogfish, stored whole at either 32°, 46.4°, or 57°F, (0°, 8°, or

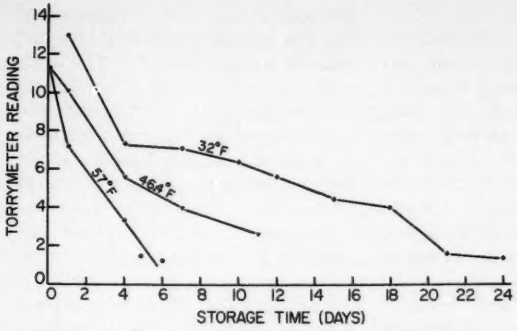

Figure 27.—Effect of storage time on Torrymeter reading on dogfish stored whole at various temperatures.

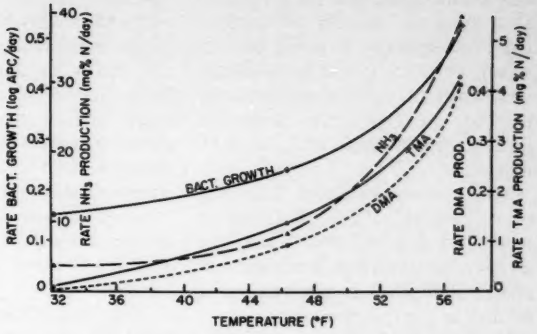

Figure 28.—Rate of bacterial growth and trimethylamine, dimethylamine, and ammonia production in dogfish stored whole as a function of temperature.

Table 3.—Regression data for flavor scores of dogfish stored whole at various temperatures as a function of certain spoilage indicators.

Storage temp. (°F)	Regression	Correlation coefficient	Intercept	Slope	n
32.0°	Flavor score vs. pH	0.81	27.12	−3.45	14
46.4		0.77	24.57	−2.88	8
57		0.97	21.30	−2.28	8
32	Flavor score vs. ammonia content	0.79	7.54	−0.06	14
46.4		0.61	7.77	−0.05	8
57		0.98	8.24	−0.03	8
32	Flavor score vs. TMA content	0.10	6.69	−0.18	14
46.4		0.96	8.32	−0.42	9
57		0.93	8.38	−0.24	8
32	Flavor score vs. log APC	0.80	10.80	−0.89	14
46.4		0.89	18.18	−2.33	10
57		0.80	15.83	−1.71	8
32	Flavor score vs. Torrymeter reading	0.86	3.41	0.42	14
46.4		0.86	1.11	0.64	10
57		0.79	2.85	0.53	8
32	Ammonia content vs. pH	0.95	−237.6	42.59	15
46.4		0.95	−246.9	43.66	8
57		0.98	−482.9	84.22	10

14°C), as a function of some chemical or physical spoilage indicators, are given in Table 3. There was good correlation between flavor and pH at each of the three storage temperatures; however, the regression lines predicted slightly different pH values at end of shelf life. These were pH 6.2 (32°F), pH 6.5 (46.4°F), and pH 6.7 (57°F). When regression analysis was performed on the combined data from the three temperatures, a pH value of 6.4 was determined at end of useful shelf life (flavor score = 6). In general, this pH value is lower than the value reached in teleosts when shelf life has expired.

Similarly, there was fairly good correlation between the flavor score and ammonia content at each of the storage temperatures; however, at the expiration of shelf life the ammonia nitrogen content varied from 26 mg % N at 32°F storage to 74 mg % N at 57°F storage.

Our main interest was to ascertain the time that dogfish can be stored under different conditions and still be acceptable after cooking. Since ammonia is volatilized during cooking, spoilage based on odor of the raw fish would probably have been judged to occur earlier than the values we are reporting. Nevertheless, it is difficult to accept raw fish with an ammonia N content of 74 mg % N as representative of marginal quality, and there is no rational explanation as to why the taste panel did not react more strongly to this high level of ammonia if it were indeed present.

Flavor score and TMA content correlated poorly with fish held at 32°F (0°C), but very well with fish stored at 46.4° or 57°F (8°C or 14°C). At 32°F (0°C), TMA content did not begin to show any significant increase until the product was on the verge of spoilage, whereas at the other two temperatures TMA production increased rapidly after a 1-day lag. There was good correlation between flavor score and bacterial count at each of the three temperatures and the average count at the end of shelf life was shown to be about 2 million per gram. We caution, however, about the risks in using absolute bacterial numbers to predict shelf life, since fish spoilage is associated more closely with the numbers of certain spoilage types of bacteria rather than with the total number of bacteria.

The principal spoilage bacteria in marine fish are the pseudomonads, and these normally constitute just a small percentage of the microflora of freshly caught fish. However, depending upon the sanitary conditions in the fishing boat or in the processing plant, their concentration on fish can be markedly increased through contact with contaminated surfaces, and

this would affect the shelf life and also the total number of bacteria (APC) at spoilage. It would be conservative to state that at the threshold of spoilage the APC would be in the millions, but one cannot state with certainty that it would be 2, 10, or 50 million.

Flavor score correlated fairly well ($r = 0.79$-0.86) with Torrymeter readings of dogfish stored at the three different temperatures. The reading at end of shelf life was predicted to be 6-7 by the regression lines.

Study 3 clearly illustrates the importance of immediate and continued icing of dogfish by fishermen while at sea. The elevated temperatures used in this study should not be considered exaggerated, but are typical of those found in dogfish landed during warm summer months and allowed to lie on deck under the sun unattended or to be stored in the ship's hold without ice.

Study 4—Rapid Estimation of Ammonia

Although the development of off-flavors, off-odors, and texture deterioration all precede the development of high concentrations of ammonia in well-iced spiny dogfish and thus limit the shelf life of this species, delayed icing and prolonged holding at elevated temperatures result in more rapid formation of ammonia. Since the dogfish caught by U.S. fishermen are primarily for export, quality losses during storage on ice are not so much a problem as is the loss of quality due to abusive handling which may well be accompanied by elevated ammonia concentrations. As stated, French and Belgian dogfish imports measure ammonia concentration of the flesh to gauge dogfish quality. Several methods are used to determine ammonia concentration, but all require either considerable time, scientific expertise, or reasonably sophisticated equipment.

Government inspectors mainly determine whether or not the quality of dogfish is acceptable for export. Certainly these inspectors are able to perform these chemical tests; however, the time and equipment required may present problems. Although precise chemical tests will probably always be necessary for accurate measurement of ammonia, we felt that a fast and simple ammonia estimation technique which inspectors might use in the plants on questionable samples might serve to screen samples and thereby reduce the number which would have to be returned to the laboratory for accurate chemical analysis. Processors, too, might find such a technique useful.

The use of ion-selective electrodes is relatively fast and easy and requires inexpensive equipment. Two basic units are needed besides the ion-selective electrode: A reference electrode and a pH/mV meter, or concentration measurements can be read directly on specific ion meters specially designed for this purpose. In Study 4 we investigated the use of the ammonia specific electrode with the Fisher Model 320 expanded scale pH meter. However, because of interfering substances, especially TMA, it soon became clear that although this electrode had the potential to measure quality (with respect to flesh TVB), it could not be used to measure the ammonia in dogfish specifically. Attempts to remove the TMA bias by coupling a TMA electrode (Chang et al., 1976) or the modified version (Brown et al., 1980) with the ammonia electrode to measure TMA and TMA plus ammonia independently were unsuccessful. On successive days, shifts in the ammonia electrode potential were common and the electrode routinely showed poor response and considerable drift.

A special time-response graph paper developed by Orion Research, Inc., was used in an attempt to clarify the data; however, this step converted the method from a field test to a laboratory test. In this procedure, periodic readings taken over about 10 minutes are plotted and the line drawn through the points is extrapolated to infinite time to obtain the desired reading.

The electrode manufacturer was contacted for assistance or suggestions and their recommendations was to soak the electrode in acid daily to remove the build up of scale which apparently was causing the problem. However, this step changes the baseline reading of the electrode and requires a standard curve to be made each day the electrode is to be used. We decided that this electrode technique would not provide processors or inspectors with a simple method for measuring the ammonia content of dogfish.

Currently, there are many kits available for the examination of contaminants or dissolved gases in aqueous samples. These kits are inexpensive, simple, rapid, and completely self-contained. One such kit, available from Chemetrics, Inc., Warrenton, Va., for the measurement of dissolved ammonia in water samples, was examined. The concentration of ammonia in portions of the same water extraction mixtures of dogfish (from Study 3) was determined using both the method of Vyncke (1968) and the Chemetrics kit.

There was excellent correlation ($r = 0.99$) between the Vyncke ammonia content and the Chemetric median values. The regression line and 95 percent confidence limits are shown in Figure 29. The slope ($b = 1.04$) of the regression line was found by a t test to not be significantly different at the 1 percent level from the slope of the hypothetical line ($B = 1.00$) denoting perfect correlation between the two results. The parametric equation for the t test was:

$$t = \frac{b - B}{S_b}$$

$$\text{where } S_b = \frac{S}{\sqrt{\Sigma n_i (X_i - \bar{X})^2}}$$

(Hald, 1957).

Although the results with this kit lack the precision of a more involved chemical analysis such as Vyncke's method, it should provide a close estimate of the ammonia content of a fish extract. It certainly should enable a processor or inspector to judge whether or not a sample meets the specification for ammonia content.

The Sigma Chemical Company also offers a chemical kit for measuring ammonia, and this device has been applied for assaying ammonia in

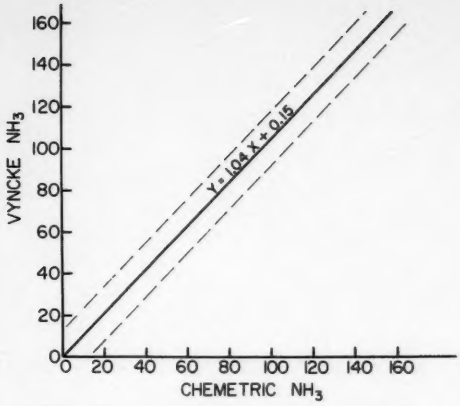

Figure 29. – Regression line and 95 percent confidence limits for Vyncke ammonia content as a function of Chemetric ammonia content.

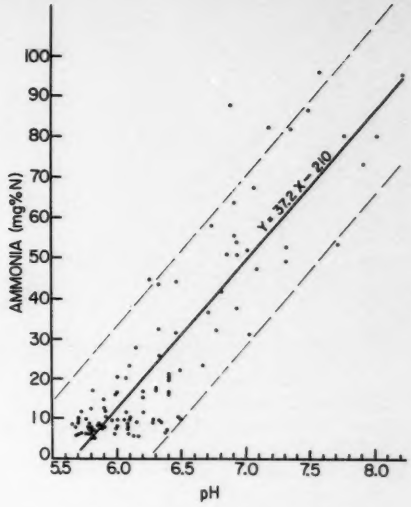

Figure 30. – Ammonia content of dogfish as a function of pH. (Regression line and 95 percent confidence limits.)

clinical samples, waste matter (Robbins and Weber, 1977), and in shrimp (Knight and Toom, 1980). Recently, Smith et al. (1980) reported on the application of this test for measuring ammonia in dogfish. The test is relatively simple and is based on the enzymatic (glutamate dehydrogenase) conversion of alphaketoglutarate to glutamate in the presence of ammonia. A special narrow bandwidth spectrophotometer is required in this text and we believe that this requirement precludes this method from the field-test category.

We found ammonia and pH to correlate well in each of our independent studies, but we did not attempt to determine the reliability of pH in predicting ammonia content from one lot of stored fish to another. All the ammonia/pH data from our experiments, with the exception of those data in which the pH exceeded 8.2, have been plotted in Figure 30. These latter data were excluded because they did not bear an apparent linear relation with the other data points. The regression line and 95 percent confidence limits ($\pm t_{0.95} \times$ S.E.) have been constructed on the figure. On the basis of these combined experiments there was very good correlation (r = 0.89, n = 112) between ammonia nitrogen content and pH; however, there also was considerable scatter among the data points. From the regression line, a pH of about 7.1 is seen to predict an ammonia nitrogen content of 55 mg % N. However, 95 percent of the time, the ammonia nitrogen content at that pH will range from about 33 to 75 mg % N.

A processor could employ a pH value of 6.6 as the cut-off point to ensure that no fish with an ammonia nitrogen content in excess of 55 mg % N would be exported. However, this plan would also reject some perfectly good fish. Although it does not appear that pH measurement can be used as a precise method for monitoring ammonia content in dogfish, there still is some potential utility in this parameter for rapid screening of fish quality on the basis of either acceptable, questionable, or unacceptable. By increasing the number of replicate samples taken for pH analysis, the average variability may be reduced and the reliability of the predicted ammonia concentration may be increased. Waller (1978) suggested using pH measurement, either obtained with surface electrode or pH paper, to assess shark quality due to ammoniation, and he designated pH ranges that would correspond to the postmortem age of iced fish.

However, Waller also pointed out that at any given time there can be a variation in ammonia content either along the length of the fish or through a cross section of the body. In dressed fish, ammonia content was higher at the anterior because of the exposed (cut) surfaces; it was also high in the vent area because the folds of the belly flaps created insulated air pockets with a slightly higher temperature than other areas of the fish, thus promoting faster bacterial growth.

Another source of ammonia variation is related to sample thickness. Ammonia formation occurs mainly on the exposed surface of fish, and therefore there will be a difference in ammonia content between two samples taken for analysis, both having the same ammoniated surface area but of different thicknesses. This variability in ammonia concentration may account for some of the scatter of the data points in Figure 30.

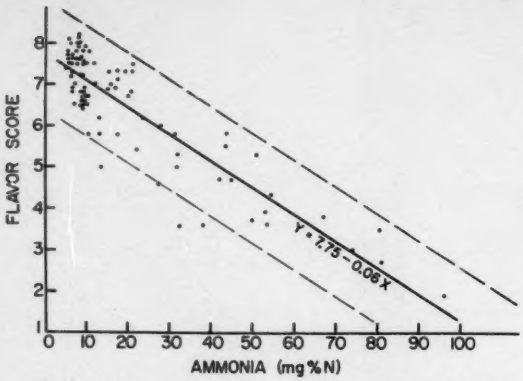

Figure 31.—Regression line and 95 percent confidence limits for flavor score of dogfish as a function of ammonia content.

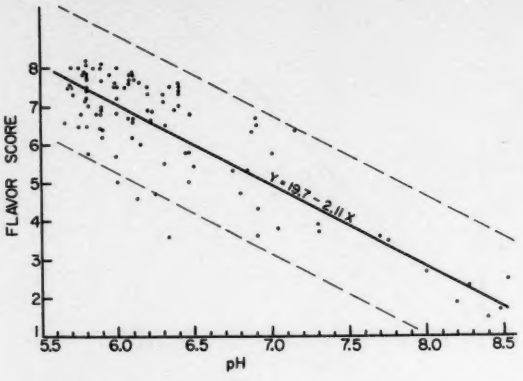

Figure 32.—Regression line and 95 percent confidence limits for flavor score of dogfish as a function of pH.

Regression analysis on flavor score as a function of ammonia nitrogen content was performed on the composite data (n = 87) of Studies 1 and 2. The correlation coefficient was found to be high (r = 0.89). The regression line and 95 percent confidence limits are presented in Figure 31. Because of the considerable scatter about the regression line, ammonia nitrogen content cannot accurately assess dogfish quality. End of useful shelf life would be predicted by an ammonia nitrogen content of about 27 mg % N. However, at this concentration the flavor rating could conceivably range from slightly poor to good 95 percent of the time. It should be remembered that flavor deterioration can be caused by the presence of other compounds in addition to ammonia.

The regression of flavor score on pH is shown in Figure 32 for the combined data (n = 102) of Studies 1, 2, and 3. There was good correlation (r = 0.84) between flavor score and pH as would be expected since flavor score, ammonia content, and pH are all interdependent. End of shelf life was predicted by a pH of 6.5. However, there will be a certain degree of unreliability with this predictor value as evidenced from the confidence limits for the regression line. Waller (1978) pointed out that physical mishandling of shark after capture can lower the quality of the fillets and this will not be reflected by the pH reading. However, he believed that a system of quality assessment could be established based on both surface pH measurement and physical appearance.

Conclusions

The shelf life of properly handled and iced spiny dogfish is comparable in length to that of properly iced gadoid fishes. Despite the high urea content of dogfish, ammonia formation does not account for quality losses during the first 2 weeks of iced storage. The process of bleeding and/or gutting seems to help extend the shelf life of iced dogfish. Abusive handling practices which allow this species to remain at elevated temperature (>32°F or 0°C) hasten ammonia formation. For processors to assess ammonia levels in dogfish intended for export, a rapid and simple field test method is needed and a self-contained kit similar to the one we tested may prove useful.

Acknowledgment

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Storage of Dressed Chinook Salmon, *Oncorhynchus tshawytscha*, in Refrigerated Freshwater, Diluted Seawater, Seawater, and in Ice

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C. M. DEWEES, and B. B. WYATT

ABSTRACT—Dressed chinook salmon, Oncorhynchus tshawytscha, *were held at 0°C in refrigerated freshwater, diluted seawater, and seawater for 7 days, and then in ice for 9 days. Another group was held in ice for the entire 16-day period, and the effects of chilling media on selected physical, chemical, microbial, and sensory changes were compared.*

Chilled water systems appeared to retard bacterial growth slightly, an advantage over ice, and fish held in diluted seawater gained less weight than fish held in freshwater and absorbed less salt than fish held in seawater. Seawater-held fish became shorter during storage. Iced storage offers several advantages over the water chilling systems, including little weight change during the first nine days and, thereafter, better appearance of belly flaps, eyes, dorsal skin color, and better belly cavity odor. Salt levels in fish stored in seawater solutions decreased by 25 percent within four days after transfer to ice, and weight gained during water storage was lost after transfer to ice.

Introduction

In the past, ice was routinely used to preserve dressed Pacific salmon, *Oncorhynchus* spp., on commercial salmon trollers. Due to increasing ice costs, its limited availability in some ports, and the time and effort required to ice fish at sea, some fishermen have adopted chilled water systems to preserve dressed salmon at sea. These systems include refrigerated freshwater, refrigerated mixtures of seawater and freshwater, refrigerated seawater, and chilled mixtures of seawater and ice (Melvin et al., 1983).

Although water chilling systems provide ease of handling and rapid cooling, an excessive uptake of water, an increase in total salt content, and bacterial growth in water systems have been identified as potential problems (Barnett et al., 1971; Roach et al., 1967; Tomlinson et al., 1974). Fishermen and salmon buyers have also asked if fish become shorter, bleached, or discolored during storage in chilled water systems, and if fish lose weight when transferred from these systems to iced storage during distribution on land.

This study was conducted to compare the effects of several chilled water systems on selected physical, chemical, microbial, and sensory changes occurring during the storage of dressed chinook salmon, *Oncorhynchus tshawytscha*, at 0°C. Chilling systems investigated were: 1) Refrigerated freshwater (RFW); 2) refrigerated diluted seawater (1/3 RSW); 3) refrigerated seawater (RSW); and 4) ice. Also investigated were the effects of transferring fish from chilled water systems to ice after 7-day storage.

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Materials and Methods

For the first phase of the study, 60 chinook salmon, weighing an average of 3.95 ± 0.57 kg, were obtained from commercial salmon trollers at Albion and Drakes Bay, Calif. The fish were eviscerated at sea, packed in ice, and transported to the University of California Food Science & Technology Department in Davis. Upon arrival and within 18 hours of capture, fish weights and total lengths were determined. Length measurements were from the tip of the snout to the extreme tip of the tail. Forty-six of the salmon were randomly transferred into 55-gallon plastic drums containing the following refrigerated storage media: RFW (20 fish); 1/3 (v/v) RSW (20 fish); and RSW (6 fish). The seawater was obtained from the University of California Bodega Marine Laboratory, Bodega Bay, Calif. The remaining 14 fish were iced in insulated containers. The plastic drums contained storage media to within 10 cm of the rim of the drum, and were loosely covered during storage at 0° ± 0.6°C. Temperatures of the storage media, the air in the cold storage room, and of two fish in each storage condition were monitored throughout the study. On day 7 of the study, eight fish from the 1/3 RSW and the RFW storage media were transferred to ice for the remainder of the experiment.

The salmon were sampled on days 0, 4, 7, 9, 11, 14, and 16. Fish held in RSW were only sampled until day 7. On each sampling day, two fish from each storage condition were randomly removed. Each fish's weight and length were recorded. A 4 cm steak

was aseptically removed just anterior to the dorsal fin for bacterial examination and salt analysis.

In the second phase of the study, 27 chinook salmon, weighing an average of 1.71 ± 0.55 kg, were caught off San Francisco Bay, Calif. Following capture, the fish were immediately eviscerated and iced. Within 12 hours of capture, the fish were transported to Davis, tagged, weighed, and measured. Twenty-four fish were randomly distributed into 55-gallon plastic drums containing refrigerated storage media: RFW (7 fish), 1/3 RSW (8 fish), and RSW (9 fish). The remaining three fish were repacked in ice. The plastic drums contained storage media to within 10 cm of the rim of the drum, and were loosely covered during storage at 0° ± 0.6°C. On day 7 of the study, fish in chilled water systems were transferred to ice.

All fish were weighed and measured at 2- or 3-day intervals during the 16 days of chilled storage, and two fish were temporarily removed from each of the storage conditions for sensory evaluation. The same fish were used for each of the sensory sessions.

Bacteriological Measurements

Aerobic plate counts (APC) of the salmon were done as follows: 21 g of fish flesh were aseptically removed from the dorsal half of the sample steak and blended with 400 ml of sterile 0.1 percent peptone water in a Waring[1] blender for 2 minutes. Duplicate 0.1 ml aliquots from appropriate serial dilutions (0.1 percent peptone water) were spread-plated on Standard Methods Agar with 0.5 percent NaCl, as suggested by Liston and Matches (1976), and incubated for 3 days at 20°C.

NaCl Analysis

The salt content of the ventral half of the sample steak was quantified using Quantabs chloride titrators (Ames Division, Miles Laboratories, Inc.). The salt content is reported as percent NaCl of wet weight. Analyses were conducted in triplicate.

Sensory Analysis

Sensory assessment of the general appearance of the whole fish was made by a trained panel of eight judges. At each judging, the panelists were presented with duplicate sets of four fish, each set containing a representative of the four storage conditions. The panelists were asked to rank the fish from most to least for the following attributes: Browning of gill cavity, discoloration of belly-flap cuts, darkness of dorsal skin color, cloudiness of eyes, and off-odor of belly cavity. Both sets of four fish were judged three times.

Statistical Analysis

Statistical differences between treatment groups were determined by analysis of variance for all the chemical and physical tests. Significance was determined using least significant difference test. The sensory data were analyzed for significant differences using the Kramer ranked two-factor analysis of variance test (Kramer, 1960; 1963).

Results and Discussion

APC results are presented in Table 1. Although differences between storage media were not consistently statistically significant, bacterial growth in fish held on ice appeared to be more rapid than in fish held in chilled water systems. Since the chilled-water fish and the iced fish were held at the same temperature, this difference may be due to more aerobic conditions present during iced storage, allowing the normal aerobic spoilage flora (Shewan, 1961) to grow more rapidly. Tomlinson et al. (1974) found RSW at −0.6° ± 0.6°C to be much more effective than ice in controlling bacterial growth with lingcod, *Ophiodon elongatus,* and sockeye salmon, *Oncorhynchus nerka.* Tomlinson's findings, and similar reports by others (Roach et al., 1961), are probably due to the lower temperature (−1.1° to −0.6°C) for the RSW-held fish.

APC data has been used to provide an index of quality in fresh raw seafoods (Liston and Matches, 1976). Good quality fish will have counts of less than 10^5/g, and acceptable quality fish will have counts of less than 10^6/g. Counts in excess of 10^6/g indicate the onset of spoilage, and counts in excess of 10^7/g are considered unacceptable for fresh raw fish (International Commission on Microbiological Specifications for Foods, 1974). Using these criteria, iced salmon had acceptable quality at day 4, marginal quality at day 7, and were unacceptable at day 11. Salmon

Table 1.—Aerobic plate counts in chinook salmon stored in ice and water systems at 0°C (32°F); mean values are for cell forming units per gram[1].

Days in storage	Storage media					
	RFW	RFW/ice[2]	1/3 RSW	1/3 RSW/ice[2]	RSW	Ice
0						$^{a}4.0 \times 10^{5}$
4	$^{a}6.5 \times 10^{5}$		$^{a}3.6 \times 10^{6}$		$^{a}2.0 \times 10^{6}$	$^{a}2.4 \times 10^{5}$
7	$^{a}4.4 \times 10^{6}$		$^{a}6.7 \times 10^{6}$		$^{a}8.5 \times 10^{6}$	$^{a}4.4 \times 10^{6}$
9	$^{a}7.2 \times 10^{6}$	$^{a}5.3 \times 10^{6}$	$^{a}4.0 \times 10^{6}$	$^{a}5.9 \times 10^{6}$	$^{a}3.2 \times 10^{6}$	$^{a}2.5 \times 10^{6}$
11	$^{a}1.6 \times 10^{6}$	$^{a}2.2 \times 10^{6}$	$^{a}1.2 \times 10^{6}$	$^{a}3.4 \times 10^{5}$		$^{a}1.8 \times 10^{7}$
14	$^{a}1.0 \times 10^{7}$	$^{a}2.1 \times 10^{7}$	$^{a}4.9 \times 10^{6}$	$^{a}2.1 \times 10^{7}$		$^{a}8.1 \times 10^{7}$
16	$^{a}5.8 \times 10^{6}$	$^{b-c}1.9 \times 10^{7}$	$^{b-c}1.3 \times 10^{7}$	$^{a}2.7 \times 10^{7}$		$^{a}5.4 \times 10^{7}$

[1] Means within the same horizontal row preceded by different letters (a,b,c) are significantly (P>0.05) different.
[2] Transferred from liquid media to ice at day 7.

[1]Mention of trade names or commercial firms does not imply endorsement by the authors or the National Marine Fisheries Service, NOAA.

in RFW and 1/3 RSW had good quality at day 4, acceptable quality at day 7, marginal quality at day 11, and were unacceptable at day 14 (RFW) or day 16 (1/3 RSW). Salmon in RSW had good quality at day 7, and acceptable quality at day 9.

The results of NaCl determinations on salmon flesh are shown in Table 2. By day 4, the RSW fish had at least a twelvefold higher concentration of salt than either the iced or RFW fish. Based on an acceptable upper limit of 0.75 percent salt[2], the RSW fish had unacceptable (1.06 percent) salt levels after only 4 days. Fish stored in 1/3 RSW had about a fourfold higher concentration of salt than the iced or RFW-held fish at day 4. When transferred to ice, about 25 percent of the salt in the flesh of the 1/3 RSW-held fish was leached out within 4 days of iced storage. A similar observation was made by Thurston and Groninger (1959) with pink salmon, *O. gorbuscha,* that were placed on ice following 8 days storage in 3 percent brine. After 6 days on ice, the sodium content in these fish was found to drop by an average of 47 percent.

NaCl uptake in fish held in water media depends on such factors as species, size, fish:RSW ratio, length of storage, and whether or not the fish are gutted (Roach et al., 1967; MacLeod et al., 1960; Wekell, et al., 1983). Salt distribution within the fish can be very uneven. Thurston and Groninger (1959) compared the salt content of the light meat, dorsal, ventral, and belly flap portions of pink salmon that had been held in brine for 8 days. The inner light meat was found to be lowest in sodium (520 mg/100 g), while the most exposed tissue, the belly flap, displayed the highest sodium content (794 mg/100 g). The tissue sampled for NaCl in this study included the belly flap, and the values reported are probably higher than the average flesh salt content.

Table 2.—Percent salt content in the flesh of chinook salmon stored in ice and water systems at 0°C (32°F)[1].

Days in storage	Storage media					
	RFW	RFW/ice[2]	1/3 RSW	1/3 RSW/ice[2]	RSW	Ice
4	[a]0.072±0.008		[a]0.327±0.068		[c]1.058±0.057	[a]0.081±0.000
7	[a]0.084±0.008		[a]0.357±0.051		[b]1.137±0.250	[a]0.096±0.021
9	[a]0.104±0.011	[a]0.084±0.008	[a]0.371±0.155	[a]0.436±0.176	[b]1.004±0.295	[a]0.120±0.000
11	[a]0.098±0.011	[a]0.084±0.000	[a]0.657±0.238	[a]0.270±0.013		[a]0.102±0.004
14	[a]0.105±0.064	[a]0.094±0.006	[a]0.522±0.000	[a]0.368±0.023		[a]0.120±0.030
16	[a]0.106±0.011	[a]0.096±0.025	[a]0.652±0.167	[a]0.270±0.013		[a]0.147±0.006

[1] Means within the same horizontal row preceded by different letters (a,b,c) are significantly ($P>0.05$) different.
[2] Transferred from liquid media to ice at day 7.

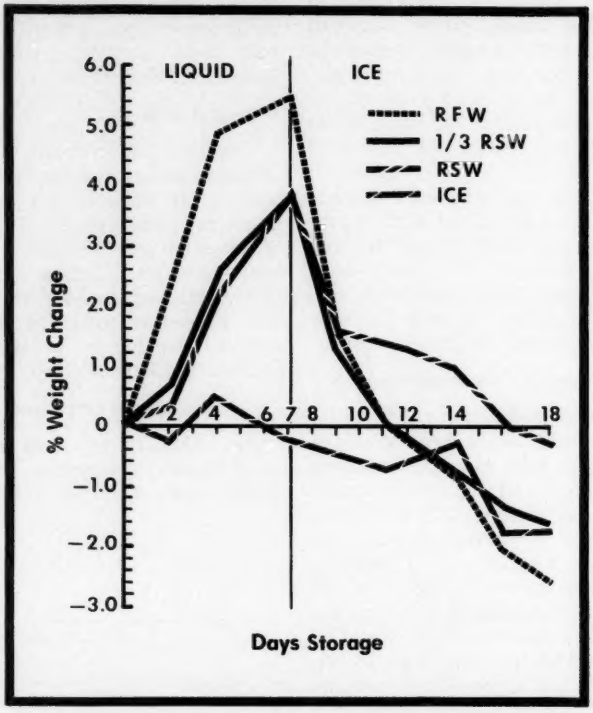

Figure 1.—Percent weight changes for salmon stored in ice and water systems at 0°C (32°F). All fish were transferred to ice at day 7.

Weight data are presented in Figure 1. Fish held in RFW, 1/3 RSW, and RSW all displayed a significant weight gain during the storage period. Within 7 days, the average weight gain was 5.45 percent for the RFW fish and 3.8 percent for the 1/3 RSW and the RSW fish. The RFW fish took up water at a much faster rate than either the 1/3 RSW or the RSW fish. The

[2]"Salt absorption of fish held in refrigerated sea water (RSW)" Activities Report, Utilization Research Division, Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, Wash., 25 April 1980.

Table 3.—Sensory evaluation of salmon stored in ice and water systems at 0°C (32°F). For each of the sensory attributes, fish are listed from least to most, left to right.

Days in storage	Sensory attributes				
	Discoloration of belly flap cuts	Browning of gill cavity	Darkness of dorsal skin	Cloudiness of eyes	Off-odor in belly cavity
4	Ice, RSW, RFW, 1/3 RSW	1/3 RSW, Ice, RFW, RSW	RFW**, 1/3 RSW, Ice, RSW**	1/3 RSW*, Ice, RSW*, RFW*	RFW*, 1/3 RSW, Ice, RSW*
7	Ice, 1/3 RSW, RFW, RSW	1/3 RSW, RFW, Ice, RSW	RFW**, 1/3 RSW, Ice, RSW**	Ice**, 1/3 RSW**, RFW**, RSW**	Ice*, 1/3 RSW*, RFW, RSW**
9	Ice**, 1/3 RSW, RSW, RFW**	Ice*, RSW, RFW, 1/3 RSW*	RFW**, 1/3 RSW, RSW, Ice**	Ice**, 1/3 RSW, RFW*, RSW**	1/3 RSW*, Ice, RSW*, RFW*
11	Ice**, RSW, 1/3 RSW, RFW**	Ice, RFW, 1/3 RSW, RSW	RFW**, 1/3 RSW, RSW, Ice**	Ice**, 1/3 RSW, RFW*, RSW**	Ice**, RFW, RSW, 1/3 RSW*
14	Ice*, RSW, 1/3 RSW, RFW*	Ice, RFW, 1/3 RSW, RSW	RFW**, 1/3 RSW, RSW, Ice**	Ice**, 1/3 RSW, RSW*, RFW**	Ice**, RFW, RSW, 1/3 RSW**
16	Ice**, 1/3 RSW, RSW, RFW**	Ice**, RFW, RSW, 1/3 RSW*	1/3 RSW, RFW, RSW, Ice**	Ice**, 1/3 RSW, RSW**, RFW**	Ice**, RFW, RSW*, 1/3 RSW**

*Significantly less ($P<0.05$). *Significantly more ($P<0.05$).
**Significantly less ($P<0.01$). **Significantly more ($P<0.01$).

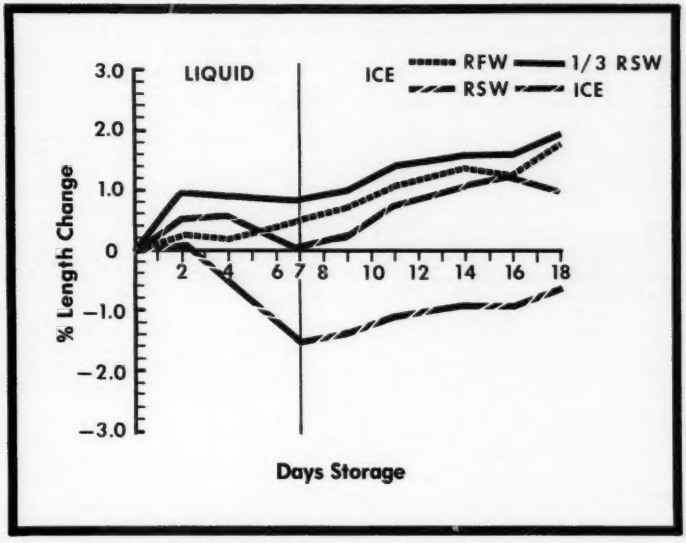

Figure 2.—Percent length changes for salmon stored in ice and water systems at 0°C (32°F). All fish were transferred to ice at day 7.

1/3 RSW and the RSW fish gained weight at a similar rate. After transfer to ice at day 7, the water taken up during water storage was quickly lost. The weight of the iced fish remained relatively constant through the first 14 days of storage. Toward the end of the study, all fish demonstrated a significant weight loss.

MacLeod et al. (1960) and Barker and Idler (1955) observed a similar weight gain for fish held in RSW. Tomlinson et al. (1965) and Roach et al. (1966), however, reported that RSW stored fish lose weight during the first 1-2 days of storage, before gaining weight. If the fish were held for several hours before being placed in RSW, they did not always demonstrate this weight loss. The salmon used in this study were held on ice for about 12 hours prior to immersion, and 2 days elapsed before the first weighing. This may account for a weight loss at day 2 for only 2 of the 17 fish stored in RSW and in 1/3 RSW.

Length data are presented in Figure 2. The 1/3 RSW and the RFW fish displayed a significant gradual increase in length over the entire storage period. The iced fish demonstrated a similar trend, although not significant due to the small ($n = 3$) sample size.

In contrast, fish held in RSW shrank significantly during the first 7 days of storage. When transferred to ice, this trend gradually reversed, but after 11 days in ice, the RSW fish were still significantly shorter than on day 0.

The results of the sensory evaluation are presented in Table 3. After 9 days storage, iced fish were judged as having less discoloration of the belly flap cuts, browning of the gill cavity, cloudiness of the eyes, and off-odor of the belly cavity than fish held in water solutions. Fish held in ice were also judged as having the darkest dorsal skin color. This indicates that skin color undergoes less bleaching when fish are stored in ice, and substantiates previous reports that chilled water systems bleach skin pigment (Ronsivalli and Baker, 1981).

Sensory data indicate significant differences between iced fish and fish held in chilled water systems; however, differences between fish held in the three water systems were not as apparent. RFW fish displayed

the most discoloration of the belly flap cuts and fading of the dorsal skin color. Both RFW and RSW fish demonstrated significant clouding of the eyes. After 11 days storage, 1/3 RSW fish were judged to smell significantly worse than the other fish.

Conclusions

Chilled water systems appear to slightly retard bacterial growth, offering a potential advantage over ice. The 1/3 RSW system is recommended over RSW or RFW, because it results in fish with less salt uptake than RSW, and less weight gain than RFW. Foul odors in RSW tanks, reported in other studies (Barnett et al., 1971; Roach et al., 1966; Peters and Dassow, 1965), were not a problem in our study.

Iced storage appears to offer several advantages over chilled water systems. Fish held in ice show little weight change during the initial 9 days of storage. Thereafter, the appearance of iced fish is significantly better in: Belly flap color, eye clarity, belly cavity odor, and dorsal skin color.

If acceptable quality throughout the typical distribution chain and at point of consumption is to be achieved, dressed chinook salmon should be held in 1/3 RSW, ice, or RFW no longer than 4 days at 0°C. Fish stored in RSW should be held no longer than 3 days.

Acknowledgments

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Observations From a Preservation and Processing Study on Atka Mackerel, *Pleurogrammus monopterygius*

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Introduction

The Gulf of Alaska and the Bering Sea contain some of the world's most abundant fishery resources. In recent years, catches of more than 2 million metric tons of groundfish have been landed, primarily by foreign fleets (Nelson and Miyauchi[1]). This fishery is basically composed of walleye pollock, *Theragra chalcogramma*; Pacific cod, *Gadus macrocephalus*; Pacific ocean perch, *Sebastes alutus;* yellowfin sole, *Limanda aspera*; and several other species including Atka mackerel, *Pleurogrammus monopterygius* (Fig. 1), of the greenling family (Hexagrammidae). Although less abundant than other species, Atka mackerel are nonetheless an important resource to foreign fishermen currently fishing Alaskan waters.

Kizevetter (1973) reports that Atka mackerel is considered the most important fish, in terms of food value, of the ten species from the family Hexagrammidae that are commercially fished by the Soviets. Japan began a large-scale commercial fishery for *Pleurogrammus azonus*, a species of greenling very similar to Atka mackerel, in Hokkaido waters in the 1950's. Thus, with the advent of the foreign groundfish fishery in Alaskan waters, Atka mackerel have also become a significant part of that fishery. Atka mackerel are extensively fished by Japan, Russia, and Poland off Kodiak Island and the Aleutian chain (Macy et al.[2]). Fishing activities are usually conducted from June to September when Atka mackerel move from the offshore to the onshore waters preparatory to spawning (Larkins, 1964).

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ABSTRACT—Chemical composition, physical and sensory characteristics, and processing yields were determined on frozen whole and butchered (heads off) Atka mackerel, Pleurogrammus monopterygius. *In addition, two methods of thawing Atka mackerel were compared. Canned products made from the Atka mackerel were evaluated organoleptically, and process yields were determined. The effect of seasonal variation on proximate composition, mineral content, and sensory characteristics was also determined. Taste panel evaluation results indicate that both fresh and canned products produced from frozen Atka mackerel were of high quality and very acceptable.*

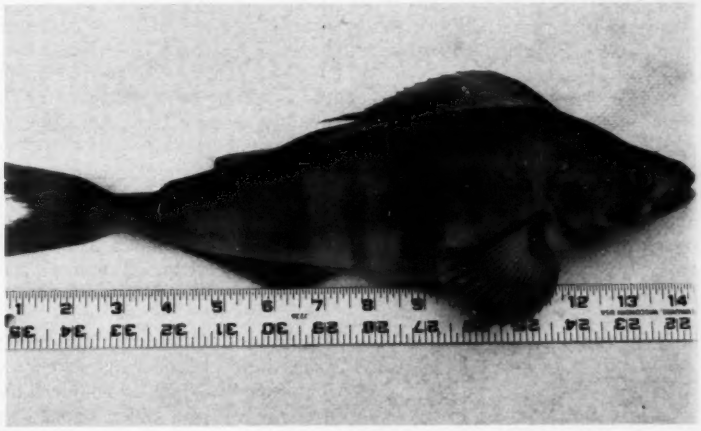

Figure 1.—Adult Atka mackerel, *Pleurogrammus monopterygius.* Photo by William L. High, NMFS Northwest and Alaska Fisheries Center, Seattle, Wash.

In 1982, the foreign fishery allocation for Atka mackerel was about 45,000 metric tons, or nearly 20 percent of the total foreign groundfish allocation in Alaska (Hasselback, 1982). Although Atka mackerel are fished by U.S. fishermen in joint ventures with foreign countries, they are otherwise of little value to U.S. fishermen because domestic markets have not yet been developed.

The Utilization Research Division of the NMFS Northwest and Alaska Fisheries Center has evaluated Atka mackerel as a possible resource for exploitation by our domestic fisheries. Although information concerning biological and ecological aspects of Atka mackerel is available, little research has been reported in the literature on the commercial usefulness of this species. Therefore, the focus of the research reported here was directed toward obtaining information concerning fillet yields, sensory attributes, and chemical composition of the frozen and canned products.

Materials and Methods

Fish Samples

The fish samples were caught in the vicinity of Albatross Bank southeast of Kodiak Island in September of 1979 by the Soviet fisheries research vessel *Poseydon* working jointly with American fisheries scientists (Reppond[3]) and in February of 1980 by the NOAA research vessel *Miller Freeman*. The September catch was frozen in 10 kg blocks, whereas the February catch was individually quick-frozen and glazed prior to boxing and shipping to the laboratory for analysis and evaluation. Due to vessel operations and delays in shipping fish from Alaska to Seattle, laboratory analyses were begun 2½ months after the September catch and 4 months after the February catch.

[3]Reppond, K. D. 1979. Preliminary report on experiments on Atka mackerel on the USSR R/V *Poseydon*, Kodiak Invesgitations-Utilization, Northwest and Alaska Fisheries Center, NMFS, NOAA, Kodiak, AK 99615. Tech. Rep. 119, 4 p.

Sample Preparation and Procedures

To determine fillet yields, fish were thawed at 34°F, weighed, measured, and then hand filleted. Fillet yields were calculated on the basis of whole and headed and gutted (H&G) fish weights. Because fillet yields were determined on the freshly landed Atka mackerel caught by the R/V *Poseydon* in September (footnote 3), they were not redetermined in this study.

To determine changes in the quality of fish held in frozen storage under accelerated temperature conditions, fish samples from the February catch were packed in master cartons lined with 1.5 ml polyethylene bags and stored at 0°F. At regular intervals of 1, 2, and 3 months, fish from each treatment were analyzed for thaw and cooked drip, oxidative rancidity (TBA value) protein in thaw drip, and sensory attributes.

To determine the effects of seasonal variation on chemical composition and mineral content, the edible flesh from 10 fish each of the September and February catches was analyzed for moisture, protein, fat, ash, and various minerals.

Raw, steamed, and smoked Atka mackerel fillets were portioned and packed in 0.5-pound (307 × 200.25) cans. Water, salt, broth, or oil were added to some cans for flavor enhancement. Each can contained about 6 ounces of meat. The cans were vacuum sealed and thermally processed at 242°F (10 psi) for 75 minutes, water cooled, and stored at 34°F until evaluated.

Process recommendations for canned Atka mackerel have not yet been established. The smoked samples were prepared as follows: Fish fillets were brined in an 18 percent NaCl solution for 10 minutes, rinsed lightly in fresh water, and drained for 10 minutes. The brined fillets were placed in a smokehouse and heated to 75°F for 1 hour in the presence of light alder smoke followed by additional heating at 120°F with light smoke for 1 hour, and final cooking at 175°F in the presence of heavy alder smoke for 30 minutes. The smoked fillets were then portioned to size and packed in 0.5-pound cans and thermally processed as previously described.

Analytical Methods

Analyses for moisture, fat, and ash were determined according to AOAC methods (Horowitz, 1980). The total Kjeldahl nitrogen method described by Taras et al. (1971) was used to determine protein in the fish. Protein in the thaw drip was analyzed according to the AOAC micro-Kjeldahl method (Horowitz et al., 1975). Mineral content, except for mercury, was determined by emission spectroscopy (Teeny et al., 1984). Mercury was determined by the Official Food and Drug Administration Vanadium Pentoxide Method (Horowitz, 1980). Chemical determinations for oxidative rancidity were done according to the method of Lemon (1975).

Comparative thaw and cooked drip determinations were made on ½-inch thick steaks with viscera and belly flaps removed. Two different methods of thawing the frozen samples were evaluated. The drip from each method of thawing was saved for protein analysis. In the first method, frozen steaks were weighed, placed on trays enclosed in plastic bags to minimize dehydration, and allowed to come to a soft-frozen state at ambient temperature. The samples were then held overnight at 34°F, drained, and reweighed. Samples thawed by the second method were weighed and placed in the inner pouch of a double plastic pouch arrangement, in which the inner pouch, containing the sample, was perforated to permit removal of drip from the sample and the outer pouch to collect the drip. The samples were then placed in a water bath at 68°F for 2 hours, drained, and reweighed. Cooked drip was determined by weighing ½-inch thick frozen steaks in aluminum containers with covers and baking at 375°F for 15 minutes, draining over a number 8 sieve for 10 minutes, and reweighing. Drained weights of the canned products were estimated by

draining samples over a number 8 sieve for 5 minutes. The oil content was determined volumetrically.

Sensory Tests

Fish samples prepared for cooked drip analysis were used to make the sensory evaluations. Samples were evaluated by a taste panel for flavor, texture, and sensory rancidity using a 5-point numerical scale. Similarly, the panel rated the canned products for the same attributes, but also included a 9-point hedonic scale to determine product acceptability.

Results

Fillet Yields and Chemical Composition

Results of the analysis for fillet yields (Table 1) are based on class length and weights and represent both whole and H&G Atka mackerel from the February catch. The data show that the yields were not dependent on the length or weight of the fish. Linear regression plots with corresponding correlation coefficients in Figures 2 and 3 show that the Atka mackerel caught in September were about twice as heavy as those caught in February (48.4 vs. 25.0 g/cm). The apparent difference in the weight of the September catch relative to the February catch reflects the state of sexual maturity of the fish and is attributed to an increase in the fat content of the flesh and growth of the internal organs including gonads. The fillet yield from the fall (September) caught fish would be expected to be less than the yield from the winter-caught (February) fish. Kizevetter (1973) made similar observations on *P. monopterygius* caught in Peter the Great Bay and in the Bering Sea. In joint research with Russian fishery scientists aboard the U.S.S.R. R/V *Poseydon*, Reppond (footnote 3) observed that the average fillet yield from hand-filleted whole Atka mackerel caught in the vicinity of Albatross Bank southwest of Kodiak Island in September 1979 was 29 percent. The reduced yield (compared with the recovery of edible product from the February-caught fish) was attributed to the well developed gonads of the fish, particularly the females, indicating that spawning was imminent.

Chemical analyses of the edible flesh from both catches show that fish caught in September were significantly (P = 0.05) higher in fat content and lower in moisture than fish caught in February (Table 2). Fujii

Table 1.—Fillet (skin off) yields from whole and H&G Atka mackerel caught in February.

Whole fish					Headed and gutted fish				
Length class (cm)	Number of fish	Whole weight (g)	Fillet weight (g)	Fillet yield (%)	Length class (cm)	Number of fish	Whole weight (g)	Fillet weight (g)	Fillet yield (%)
28	2	256	106	41.41					
29	1	298	106	35.57	24	4	252	134	53.17
30	1	383	151	39.43	25	6	268	134	50.00
31	7	371	147	39.62	26	9	304	163	53.62
32	12	402	163	40.55	27	5	346	167	48.26
33	10	411	153	37.23	28	5	312	157	50.32
34	3	402	161	40.05	29	8	314	166	52.87
35	6	412	159	38.59	30	5	317	186	58.68
36	2	520	217	41.73	31	1	349	195	55.87
Average 32.5		384	151	39.3	27.2		300	163	52.9

Table 2.—Proximate composition and sensory attributes of the edible flesh of Atka mackerel caught in September and February.

Catch date	Number of fish	Proximate composition (%)				Sensory attributes[1]		
		Moisture	Protein	Fat	Ash	Flavor	Texture	Rancidity
September	10	73.7±2.1	17.4±1.5	6.4±1.7	1.3±0.2	4.5±0.5	4.5±0.8	4.1±0.9
February	10	79.0±1.3	17.5±0.8	2.3±1.2	1.2±0	4.2±0.4	4.8±0.4	4.2±0.8

[1] Scale of 1–5 with 5 indicating a fish with good flavor, normal (firm) texture, and no rancidity.

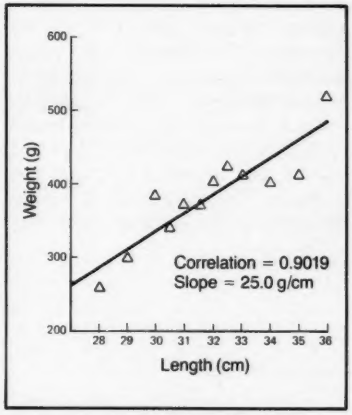

Figure 2.—Length/weight regression plot for whole Atka mackerel, February 1980.

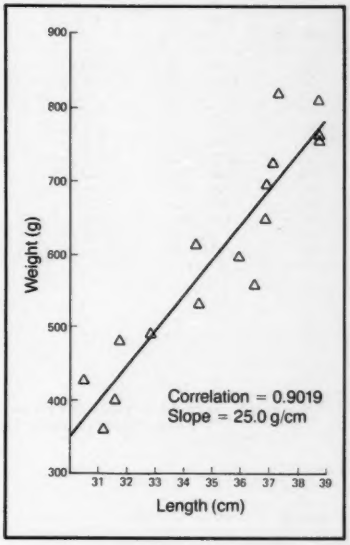

Figure 3.—Length/weight regression plot for whole Atka mackerel, September 1979.

(1954) and Kizevetter (1973) found that the fat content of Atka mackerel is at its highest during the prespawning period from May through October depending on fishing areas. There was no difference between the protein content of the September-caught fish and the protein content of fish caught in February.

The mean metal concentration of the elements is presented in Table 3. Analysis of data by the Student *t* test showed that the September catch contained significantly higher levels of copper, potassium, and sodium than the February catch. For the remainder of the elements, no significant differences were found between the two catches.

Table 3.—Mineral composition of Atka mackerel fillet muscle caught in September and February southeast of Kodiak Island.

Mineral	Composition (μg/g) September catch	February catch
Ca	143±31.9	161±50
Cr	0.134±0.036	0.109±0.011
Cu	0.797±0.107	0.489±0.034
Fe	7.44±1.41	5.07±1.12
Hg	0.016±0.002	0.012±0.004
K	5,210±180	1,780±201
Li	0.029±0.004	0.116±0.014
Mg	292±16	303±16
Mn	0.123±0.012	0.099±0.019
Na	650±109	385±34
P	2,700±82	2,440±66
Sr	0.338±0.107	0.295±0.107
Zn	4.42±0.59	5.72±0.52

Frozen Storage Studies

The quality of whole and H&G Atka mackerel remained good throughout the 3 months of frozen storage (Table 4). Mean flavor scores decreased from 4.2 for whole and H&G fish to 3.2 and 3.5, respectively. Texture remained almost unchanged throughout the 3 months of frozen storage. Similarly, no significant changes were observed in sensory rancidity scores as a result of treatment or time in storage.

Results of chemical analyses for oxidative rancidity (TBA value, Table 4) indicated no significant changes in rancidity during the first 2 months of frozen storage in the laboratory. However, a significant and unexplained increase in TBA values was observed after 3 months of frozen storage. At this time, the samples had been frozen for a total of 7 months (3 months in the laboratory plus 4 months aboard the R/V *Miller Freeman*). The increase in TBA values indicated a potential rancidity problem not detected by the taste panelists.

Data showing the effect of frozen storage on the formation of thaw and cooked drip in steaks cut from fish stored at 0°F for 1, 2, and 3 months are presented in Table 5. These data show that fish thawed at 34°F produced slightly less than half of the amount of drip as that produced by fish thawed at 68°F (average combined thaw drip for whole and H&G fish at 34° and 68°F, respectively, was 2.8 percent and 5.4 percent). Because only small differences were observed in the amount of thaw drip between the whole and H&G fish samples within each thaw temperature group (34°F vs. 68°F), we can assume that time in frozen storage in this experiment did not play a significant role in the process of thaw drip formation. Miyauchi et al. (1962) reported that the formation of thaw drip in Pacific cod was dependent on storage temperature and time. Cooked drip data show a slight decrease in drip with storage time, but there was no significant difference in the amount of cooked drip from the whole and H&G fish.

Protein content in the drip from samples thawed at 34°F and 68°F are presented in Table 6. The content of protein in the drip of the samples thawed at 34°F was slightly greater than the protein content in the samples thawed at 68°F. The differences in protein content, however, appeared to be related more to the methods of thawing than to the experimental storage conditions. Differences in protein content in the drip

Table 4.—Sensory[1] and chemical evaluations of Atka mackerel caught in February and held in frozen storage for 3 months.

Laboratory storage time[2] (months)	Form	Flavor	Texture	Rancidity	TBA (μmoles malonaldehyde/100 g fillet muscle)
0	Whole fish	4.2±0.4	4.8±0.4	4.2±0.8	0.29±0.07
	H&G	4.2±0.6	4.8±0.4	4.5±0.8	0.22±0.05
1	Whole fish	3.5±0.6	4.8±0.5	4.5±0.6	0.04±0.02
	H&G	4±0.8	4.5±0.6	4.8±0.5	0.13±0.02
2	Whole fish	3.2±1.1	4.3±1.1	3.7±1.4	0.19±0.04
	H&G	3.5±0.6	4.2±1.1	4.6±0.6	0.40±0.36
3	Whole fish	3.2±0.9	4.8±0.5	4.2±1	0.91±0.21
	H&G	3.5±0.6	4.2±0.5	4.2±1	0.91±0.24

[1] Sensory scale of 1–5 with 5 indicating a fish with good flavor, normal (firm) texture, and no rancidity.
[2] After frozen storage in the laboratory, these fish samples had been frozen for 7 months (3 months in the laboratory plus 4 months aboard the R/V *Miller Freeman*).

Table 5.—Thaw and cooked drip analyses of steak samples cut from whole and H&G Atka mackerel caught in February.

Laboratory storage time[1] (months)	Form	34° thaw (%)	68° thaw (%)	Cooked drip (%)
0	H&G	1.72±0.75	5.49±0.53	20.31±1.44
	Whole	2.60±0.23	6.27±2.45	17.88±1.08
1	H&G	2.97±0.28	5.95±0.66	18.25±0.91
	Whole	3.62±0.22	5.31±0.66	17.07±1.40
2	H&G	2.63±0.77	4.50±0.97	14.98±1.32
	Whole	2.25±0.47	4.43±0.49	13.51±0.58
3	H&G	3.38±0.80	6.23±0.81	
	Whole	3.25±1.26	5.09±0.87	

[1] After frozen storage in the laboratory, these fish samples had been frozen for 7 months (3 months in the laboratory plus 4 months aboard the M/V *Miller Freeman*).

Table 6.—Protein content (%) in the thaw drip from steaks cut from whole and H&G frozen Atka mackerel caught in February.

Laboratory storage time[1] (months)	Form	34° thaw (%)	68° thaw (%)
0	H&G		8.38
	Whole fish		8.53
1	H&G	9.97	8.47
	Whole fish	9.81	8.92
2	H&G	9.60	8.57
	Whole fish	9.42	8.07
3	H&G	7.68	8.26
	Whole fish	7.42	7.69

[1] After frozen storage in the laboratory, these fish samples had been frozen for 7 months (3 months in the laboratory and 4 months aboard the R/V *Miller Freeman*).

Table 7.—Taste panel and drained weight yield evaluations of canned Atka mackerel.

	Sensory examinations					
	Sensory attributes[1]			Overall acceptability (1–9)	Drained weight	
Can treatment[3]	Texture (1–5)	Oiliness (1–5)	Flavor (1–5)		Percent oil	Percent yield
I	3.8±0.5	3.5±0.6	3.5±0.6	6.2±0.5	17.7±1.6	83.0±2.1
II	3.8±0.5	3.8±1	4.0±0	6.5±0.6	3.9±0.5	83.2±2.3
III	3.8±0.5	4.0±1.1	3.5±0.6	6.0±0	4.7±1.1	85.0±1.7
IV	3.8±0.5	3.8±1	4.0±0.8	7.0±0.8	12.8±2.0	81.4±1.4
V	3.8±0.5	3.8±1	3.8±0.5	6.2±0.5	4.3±0.9	81.6±1.3
VI	3.5±0.6	4.0±1.1	3.8±0.5	6.2±0.5	5.4±2.0	82.6±0.4
VII	4.0±0	3.5±1.3	3.8±0.5	6.5±0.6	5.6±0.8	87.5±1.4
VIII	3.8±0.5	3.2±1.2	4.2±0.5	7.0±0	17.1±0.7	89.5±0.8

[1] Scale of 1–5 with 5 indicating a fish with normal (firm) texture, no oiliness, and good flavor.
[2] Hedonic scale of 1–9 with 9 indicating a fish with high acceptability.
[3] Treatment codes and treatments:
I Raw, skin on, ½ teaspoon salt, 1 tablespoon salad oil.
II Raw, skin on, ½ teaspoon salt, 1 tablespoon water.
III Raw, skin on, ½ teaspoon salt, no other additives.
IV Raw, skin off, ½ teaspoon salt, 1 tablespoon salad oil.
V Raw, skin off, ½ teaspoon salt, 1 tablespoon water.
VI Raw, skin on, ½ teaspoon salt, no other additives.
VII Precooked, ½ teaspoon salt, 1 tablespoon water.
VIII Precooked, ½ teaspoon salt, 1 tablespoon salad oil.

from the H&G fish and whole fish were small.

Evaluation of Canned Fish

Taste panelists found that canned Atka mackerel (canned raw, precooked, or smoked) had an acceptable flavor which was further enhanced by the addition of vegetable oil and salt and to lesser degree by the addition of salt and broth. Taste panelists found that canned products had a slight but acceptable oily mouthfeel (Table 7).

The apparent higher drained weight yield for the precooked canned Atka mackerel is explained by the fact that the precooked samples lost most of their cooked drip during the precooked procedure. Thus, when retorted, they appeared to lose less drip than did the canned products prepared from raw fish.

Summary

Although the work reported here is only preliminary, the results indicate that Atka mackerel is a highly edible species of fish that should find a ready acceptance in the U.S. market. Organoleptic evaluations of the fish fillets indicate that the fish is highly desirable. The addition of a slight amount of vegetable oil to the canned products enhanced its acceptability. During the spawning season, Atka mackerel have a higher fat content which imparts a more distinct oily flavor and mouthfeel.

For the same fish length, the fish caught in September were heavier than the fish caught in February. In addition to a higher fat content, Atka mackerel caught in September had significantly higher concentrations of copper, potassium, and sodium than those caught in February. Protein content in the edible portions was not significantly different between the September-caught and the February-caught fish.

Although TBA values, as a measure of rancidity, increased after 3 months of storage at 0°F in the laboratory, Atka mackerel was surprisingly stable and resistant to rancidity as detected by sensory evaluation.

Headed and gutted Atka mackerel yielded about the same amount of cooked drip as the whole fish. Thawing in 68°F water resulted in higher drip losses than thawing at 34°F. Slightly more protein was observed in the drip from the air-thawed fish samples than in the drip from the water-thawed samples.

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Keeping Quality of Fresh and Frozen Sand Lance, *Ammodytes* sp.

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Introduction

Sand lance, *Ammodytes* sp., also commonly referred to as sand eels, are elongated, slender, round-bodied fish which resemble small eels (Fig. 1), swim with an undulating motion in large schools, and grow to a maximum length of about 6 inches (Bigelow and Schroeder, 1953). In the western Atlantic Ocean their range extends from about Cape Hatteras to Labrador. These fish are usually found in shoal waters either along the immediate coast or on offshore banks having a sandy bottom. With the aid of their long pointed snout, they occasionally burrow in the sand, hence the name sand eel.

Within recent years there has been an explosion in the numbers of sand lance in the northwest Atlantic (Meyer et al., 1979). It has been suggested that this phenomenon may be associated with the decline in the Atlantic mackerel, *Scomber scombrus*, and Atlantic herring *Clupea harengus*, stocks (Morse, 1982). It was also proposed that the increased abundance on the Grand Banks resulted from the depletion of Atlantic cod, *Gadus morhua*, (Winters, 1983). In 1974, the percentage of sand lance larvae comprising the total winter larval fish population in the Mid-Atlantic Bight, Southern New England area, and Georges Bank was about 50 percent, whereas by 1979 this figure had reached close to 90 percent. During that period, the abundance estimates increased by a factor of 20 times (Sherman et al., 1981). These sand lances purportedly represent a threat to important commercial species such as Atlantic cod, haddock, *Melanogrammus aeglefinus*; herring, etc., in that not only are they preying on their young larval forms, but are also competing with them for available food (Hendrickson, 1979).

There is no directed commercial fishery for sand lance on the U.S. east coast. There is a small limited domestic market for the bait industry and an even smaller ethnic market for human consumption (Smith, 1978). In Europe, particularly Denmark and West Germany, sand lance from the North Sea form the basis of an important industrial fishery where they are reduced to fish meal and oil (Borgstrom, 1962; Kietzmann, 1969).

In 1978, the New England Fishery Development Program sponsored a study to determine the feasibility of catching sand lance off southern New England (Stellwagen Bank) and the results were reported by Smith and Testaverde[1]. The NMFS Northeast

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[1]Smith, R. M., and S. Testaverde. 1978. Development of a day-trawler fishery for sand launce (Ammodytidae) off the coast of New England: Technical and biological considerations. Speech presented at the 23rd Annual Atlantic Fisheries Technological Conference, Williamsburg, Va.

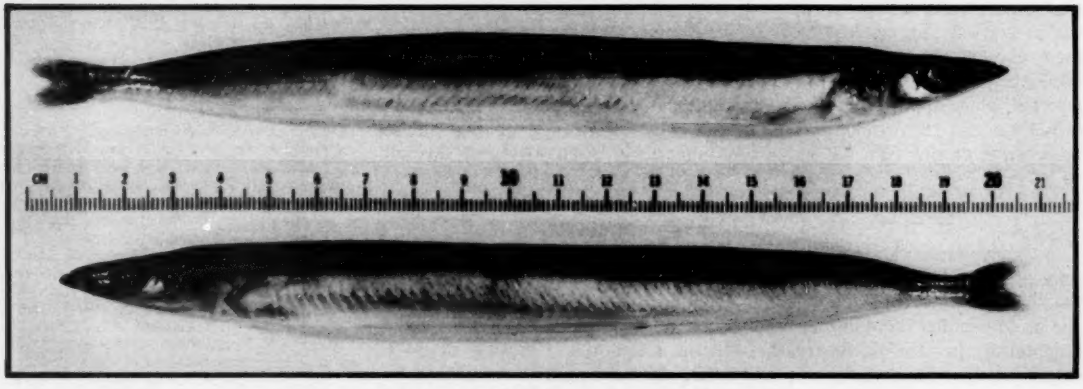

Figure 1.—Sand lance, *Ammodytes* sp., from Stellwagen Bank.

Fisheries Center's Gloucester Laboratory participated in that study by comparing methods of holding the sand lance on board the fishing vessel, and also by determining the species' fresh and frozen storage characteristics with regard to its potential as a human food. This paper reports the results of that investigation.

Materials and Methods

The sand lance were caught on Stellwagen Bank in July by a commercial trawler using a small-mesh net in the cod end. One portion of the catch was immediately iced on board ship in standard wood fish boxes (125-pound capacity) and another portion was placed in an insulated tank containing chilled seawater (CSW) prepared by mixing one part seawater with one part ice. The fish were received at the laboratory the same day they were caught. The iced and boxed fish were placed in a walk-in refrigerator at 34-36°F. The CSW tank was relocated in the pilot plant and connected to a recirculating refrigeration unit set to maintain a water temperature of 32-34°F. After 2 days post-mortem, the fish were removed, iced in conventional boxes, and also stored in the refrigerator.

Periodically, samples from both treatments were assayed for: Aerobic plate count (68°F) using the agar medium of Lee and Pfeifer (1974); peroxide value by an iodine titration procedure (Riemenschneider et al., 1943) on either a chloroform-anhydrous sodium sulfate extract of the flesh (Dyer and Morton, 1956) or a chloroform-methanol extract (Bligh and Dyer, 1959); trimethylamine (TMA) content by a modification of the Dyer picrate method (Tozawa et al., 1971). For a Torrymeter reading (Jason and Richards, 1975), six measurements were made on the lateral line along the entire length and the results averaged. For sensory evaluation, the fish were headed and eviscerated, batter-breaded, and deep fried in corn oil. The cooked product with breading removed was rated for flavor and texture on a scale of 1 to 9 (9 = excellent, 5 = marginal) by 12 laboratory personnel with experience in tasting fish of variable quality. Shelf life was considered to have expired when the sensory score value reached 6.

For the frozen storage study, the 2-day post-mortem fish, either iced or held in CSW, were headed and gutted, batter-breaded, frozen and then either air-packed in 2 mil polyethylene bags or vacuum-packed in bags made from Curlon S-660[2] (nylon-PVDC-surlyn) and then stored at 0°F. Samples from the four different treatments (ice-air, ice vacuum, CSW-air, CSW-vacuum) were periodically examined for organoleptic quality and peroxide value, and for extractable protein nitrogen (EPN) by the procedure of Ravesi and Anderson (1969).

For the proximate analysis, moisture content was determined by drying to constant weight in an air oven at 212°F (100°C). Ash was assayed by incineration in a muffle furnace at 1,022°F (550°C). Lipid content was determined by a methanol-chloroform extraction procedure (Bligh and Dyer, 1959). Nitrogen content obtained by micro-Kjeldahl method was multiplied by 6.25 to obtain protein value. All statistical analyses were performed on a programmed HP-97 calculator.

Results and Discussion

Composition

Sand lance chemical composition is presented in Table 1. With a fat content greater than 5 percent, these fish would have to be classified as fatty. However, the fat content of pelagic fish usually varies seasonally and it is not known whether the fat content determined in this study was minimal, maximal, or average. The species of sand lance we studied was most probably American sand lance, *Ammodytes americanus*. Sidwell et al. (1974) reported a lipid content of 1.5 percent for *Ammodytes lancedatus*, and whether this lower value represents a species or seasonal differences is not known.

Fresh Study

Sand lance held in CSW generally remained in rigor longer compared with the fish stowed in ice. This may have been due to the more rapid lowering of the body temperature by the CSW. Duration of rigor in fish is a function of both the storage temperature and the time required to equilibrate to that temperature. The appearance of the CSW fish was also slightly better because there was less crushing and the CSW had washed the surface slime off the fish. At the end of the initial 2-day holding period, the chilled seawater had acquired an off odor, probably the result of bacterial growth. During subsequent storage in ice there was not much of an apparent difference between the two treatments except for frequency of burst or blown bellies which was greater among fish initially held in CSW. This condition occurs in fish caught when they have been heavily feeding and their digestive tract contains a high content of proteolytic enzymes which dissolve the belly tissues. In Figure 2, percent burst bellies for the two treatments, determined on randomly selected samples of 40 fish per testing, has been plotted as a function of storage time.

Based upon the appearances of the eyes and odor of the flesh, fish from both treatments were considered to be in very good condition after 5 days and in good condition after 8 days. After 12 days the eyes were slightly cloudy and the flesh had developed an

Table 1.—Chemical composition of sand lance.

Form	Composition (%)			
	Water	Protein	Lipid	Ash
Whole	73.2	17.1	6.9	2.8
Edible portion	75.4	18.3	5.1	2.0

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

oily, fishy odor which had intensified by the 15th day.

The average flavor scores for the fish prestored in CSW were slightly lower throughout a 15-day storage period compared with the all-iced samples (Fig. 3). A significant flavor difference (5 percent level) based on a *t* test was only observed at the eighth day of testing. End of iced shelf life for both treatments occurred at 14 days. It is believed that the slight downgrading of the flavor scores of the CSW samples was due to an increased degree of rancidity in these fish. The more rapid rate of peroxide accumulation in these samples compared with the all-iced samples supported this opinion (Fig. 4). The CSW fish probably absorbed some salt which is known to accelerate the rate of lipid oxidation.

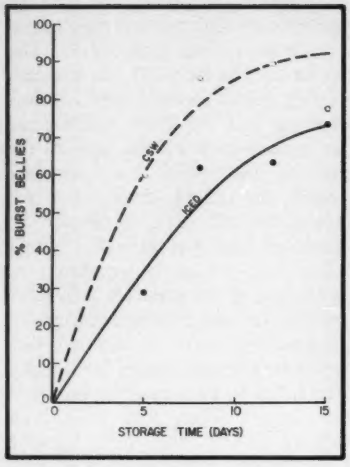

Figure 2.—Effect of stowage method aboard ship on frequency of burst bellies among sand lance held in ice.

The texture of the CSW fish was scored slightly lower throughout storage compared to all-iced fish, because of a softening. However, textural deterioration was not the limiting quality factor governing storage life.

Production of trimethylamine was very similar for both treatments (Fig. 5) and at spoilage the TMA-N content was estimated as 24 mg/100 g. The high correlation coefficient ($r = 0.96$) determined for TMA content and flavor score suggests that TMA content might be a useful spoilage indicator for fresh sand lance.

There was a progressive decrease in average Torrymeter readings during storage, but no significant difference between the two treatments (Fig. 6). In some instances, particularly in the later stage of storage, there was a large variation in readings among the 15 random fish which constituted the sample. At the onset of spoilage the meter reading was estimated from regression analysis as 11-12. With gadoid species we have usually observed a meter reading of 5-7 at incipient spoilage. There was very good correlation ($r = 0.93$) between log meter reading and flavor score. Thus, if used judiciously, this instrument might be employed to assess quality of even small fish such as sand lance.

Frozen Study

Throughout a 50-week storage period at 0°F the ice-vacuum samples showed the best flavor stability (Fig. 7). Frozen storage lives were estimated from regression lines to be: 40 weeks for either the ice-air or CSW-vacuum fish; 25 weeks for the CSW-air samples. Quality failure was induced by the development of oxidative rancidity which seemed to have been enhanced in samples either packaged in an air atmosphere or initially held in CSW. The peroxide levels reflected the sensory results, that is, the ice-vacuum treatment, which received the highest flavor scores, also contained the least amount of peroxides (Fig. 8). In both the fresh and frozen study, comparative peroxide determinations were made on a chloroform-sodium sulfate

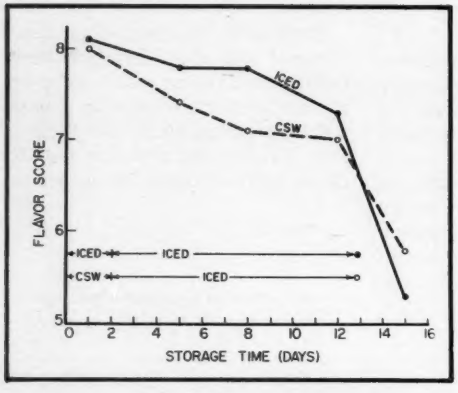

Figure 3.—Effect of shipboard stowage method on flavor score of sand lance held in ice.

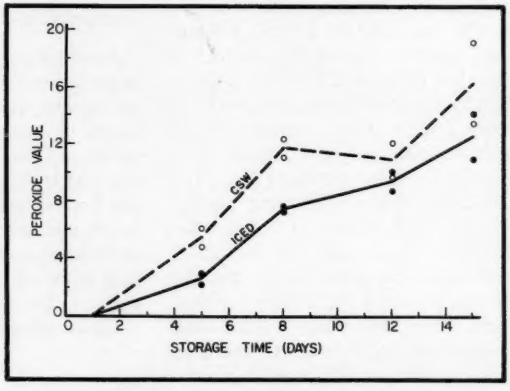

Figure 4.—Effect of stowage method aboard ship on peroxide value of sand lance held in ice.

extract and a Bligh-Dyer chloroform-methanol extract. There was essentially no difference in the result and for future work the chloroform-sodium sulfate method would be recommended because of its simplicity. Takama et al. (1978) also reported the problem of rancidity in frozen sand lance and they were able to suppress the reaction by treatment with a water dispersible tocopherol mixture.

The texture of the sand lance during frozen storage was remarkably stable. Over a 60-week period the average organoleptic texture score had only decreased by 1 point on a 9-point scale and the final rating was "good." Yet, during storage, there was a sharp steady decrease in extractable protein nitrogen (Fig. 9) which would seem to indicate that the proteins were being denatured at a greater rate than indicated by taste tests. It is possible that products of lipid degradation caused denaturation of the sarcoplasmic proteins and this would account for the change in EPN. The ice-vacuum treatment, which showed the least rancidity, also had the lowest loss of EPN. Correlation between sensory texture score and EPN was only fair (r = 0.64); however, the EPN value signalling

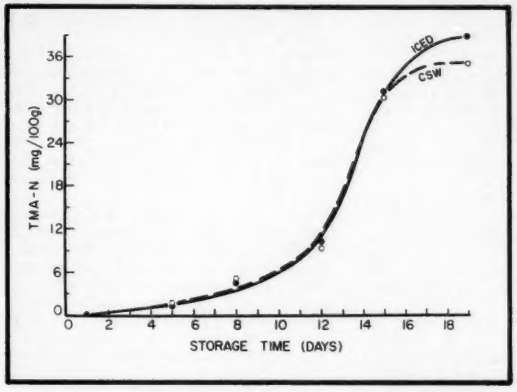

Figure 5.—Effect of shipboard stowage method on trimethylamine content of sand lance held in ice.

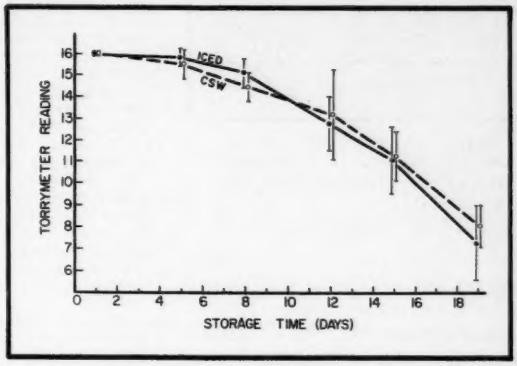

Figure 6.—Effect of shipboard stowage method of Torrymeter readings of sand lance held in ice.

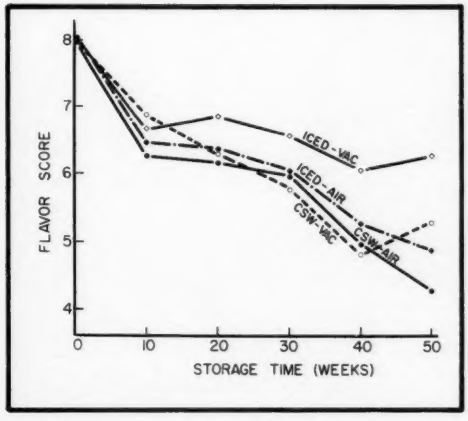

Figure 7.—Flavor score of sand lance treated in various manners and stored at 0°F.

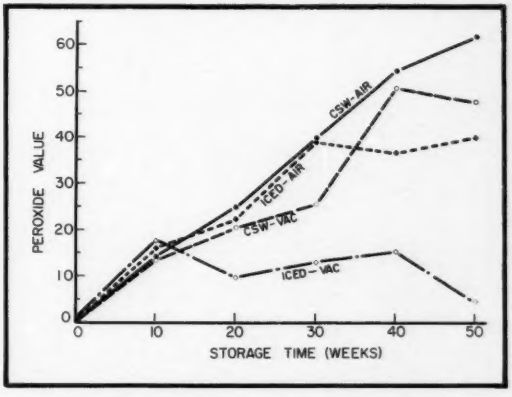

Figure 8.—Peroxide value of sand lance treated in various manners and stored at 0°F.

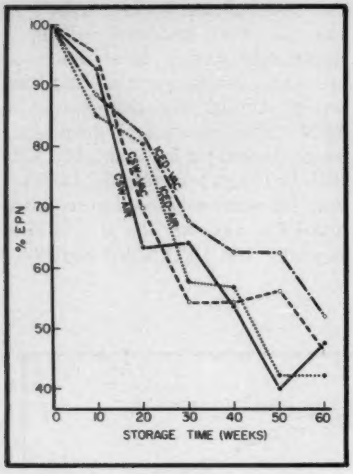

Figure 9.—Extractable protein nitrogen content of sand lance treated in various manners and stored at 0°F.

unacceptable texture was estimated from the regression line as 24. For gadoid species we have usually observed a value of about 30.

Summary

Sand lance have good potential as a food fish. Breaded and fried, their gustatory characteristics are akin to fried smelt. Since sand lance are prone to the development of oxidative rancidity, appropriate protective measures should be taken when long-term storage is anticipated. Although the transport of whole fish in CSW has several advantages, it is not advocated that sand lance be held in this medium beyond 48 hours because of the potential adverse effects on flavor during prolonged frozen storage.

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The Effect of Denil Fishway Length on Passage of Some Nonsalmonid Fishes

EMIL SLATICK and LARRY R. BASHAM

ABSTRACT—This paper documents the success of passage of some nonsalmonid fishes through Denil-type steeppass fishways of varying length and slope. Length ranged from 7.9 m (26 feet) to 20.1 m (66 feet), and slope ranged between 23.3 and 28.7 percent. American shad, Alosa sapidissima*; common carp,* Cyprinus carpio*; chiselmouth,* Acrocheilus alutaceus*; northern squawfish,* Ptychocheilus oregonensis*; Pacific lamprey,* Lampetra tridentata*; and suckers,* Catostomus *sp., were observed at Bonneville and McNary dams on the Columbia River and Little Goose Dam on the Snake River from 1971 to 1979. These fish were successful in ascending the 7.9 m (26-foot) fishway, and all but the common carp ascended the 15.2 m (50-foot) fishway. When the length was extended to 20.1 m (66 feet), no American shad or resident freshwater fish were observed ascending and passing through the Denil. Salmonids and Pacific lamprey, however, were able to successfully pass through all lengths of Denil fishways tested. These observations indicate that Denil ladders of selected length could be used, if desired, to pass salmonid fishes over small barriers while denying upstream access to certain unwanted nonsalmonids.*

Introduction

Steeppass Denil-type fishways have been used in Alaska and the Pacific Northwest to pass migrating adult salmonids over small barriers (Zeimer, 1962, 1965[1]; Washington Department of Fisheries, 1968). Denil fishways ranging from 9.1 m (30 feet) to 27.4 m (90 feet) long and angled at slopes of 19.7-26.2 percent have been used successfully to pass coho salmon, *Oncorhynchus kisutch*; sockeye salmon, *O. nerka*; and pink salmon, *O. gorbuscha,* in Alaska (Ziemer, 1962; footnote 1). The National Marine Fisheries Service (NMFS) has successfully used Denil fishways up to 20.1 m (66 feet) long to pass chinook salmon, *O. tshawytscha*; coho salmon; sockeye salmon; and steelhead, *Salmo gairdneri*, during experiments in the Columbia River Basin, (Ebel, 1974; Slatick, 1975; Slatick et al., 1975; Thompson[2]).

While the NMFS was testing Denil fishways of varying lengths to pass Pacific salmon, many observations were made on the passage of a variety of nonsalmonid fishes, including American shad, *Alosa sapidissima*; common carp, *Cyprinus carpio*; chiselmouth, *Acrocheilus alutaceus*; northern squawfish, *Ptychocheilus oregonensis*; Pacific lamprey, *Lampetra tridentata*; and suckers, *Catostomus* sp. This paper documents the varying degrees of passage success shown by the different species and points out a potential management implication.

Equipment and Procedures

The Denil fishway design used by the NMFS was a Model A described by Ziemer (1962). It was an aluminum flume made of sections that were 3.1 m (10 feet) long, 0.56 m (22 inches) wide, and 0.7 m (27 inches) high containing internal baffles for control of water velocity (Fig. 1). Clearance within the baffles (open area) was 0.36 m (14 inches) by 0.56 m (22 inches). Sections were bolted or welded together to achieve the desired length of ladder. The Denil fishways tested ranged from 7.9 m (26 feet) to 20.1 m (66 feet) long and were inclined at slopes of 23.3-28.7 percent, depending on the experimental site. During operation, the Denils were completely filled with water and carried a flow of approximately 0.16 m^3/second (5.5 $feet^3$/second).

During the experiments, Denils were installed in the regular fishways at Bonneville and McNary Dams on the Columbia River and at Little Goose Dam on the Snake River. At Bonneville Dam, Denil fishways were also operated in the Fisheries Engineering Research Laboratory (Slatick, 1975). Observations on the passage of nonsalmonid fishes occurred over an 8-year period, from 1971 to 1979. Most of the data were obtained between June and August each year when maximum numbers of resident and anadromous nonsalmonid fishes were in the fish ladders.

Observations

Resident freshwater fish observed in the fish ladders at Bonneville Dam

[1]Ziemer, G. L. 1965. Steeppass fishway development. Addenda to Inf. Leafl. 12. Unpubl. manuscr., 5 p. Alaska Dep. Fish Game, Juneau, AK 99801.

[2]Thompson, C. S. 1976. Evaluation of the adult salmonid trap installed in the Bradford Island "A" branch fishladder, Bonneville Dam. Unpubl. manuscr., 48 p., append. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Prep. for U.S. Army Corps Engr., Portland, Oreg. under Contract DACW57-75-F-0547.)

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included common carp, northern squawfish, and suckers. Both suckers and northern squawfish were reported passing through a 7.9 m long (26-foot) Denil with a slope of 24 percent at Bonneville Dam in 1971 (Slatick, 1975). In 1979, the slope was increased to 27.8 percent, and common carp, northern squawfish, and suckers were observed passing through the Denil.

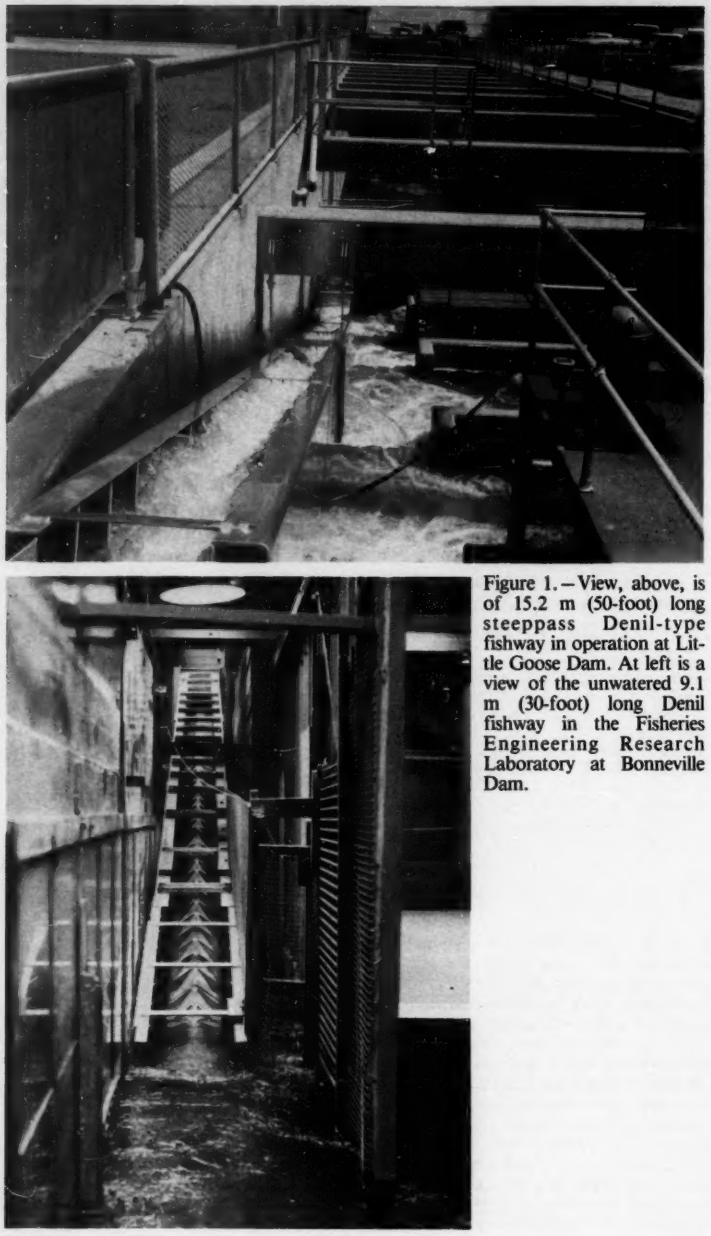

Figure 1.—View, above, is of 15.2 m (50-foot) long steeppass Denil-type fishway in operation at Little Goose Dam. At left is a view of the unwatered 9.1 m (30-foot) long Denil fishway in the Fisheries Engineering Research Laboratory at Bonneville Dam.

A longer 15.2 m (50-foot) Denil (28.7 percent slope) was used at Little Goose Dam on the Snake River, and northern squawfish, suckers, and chiselmouth were seen successfully passing over this fishway over a 5-year period. Common carp, however, were observed entering the Denil, but proceeded only a short distance before either jumping out or turning around and descending the ladder.

The length of a Denil apparently affected the passage of carp; carp readily passed the shorter fishway at Bonneville Dam but rejected the longer fishway at Little Goose Dam. Although the Denil fishways were located at two different dams, similar conditions existed: Carp were present in the regular fish ladders, Denil slopes were identical, and the observations were conducted during the summer. The only known difference other than location was the length of the Denil.

An even longer Denil adversely affected passage of both northern squawfish and suckers. These fish, which had readily ascended the 15.2 m (50-foot) fishway at Little Goose Dam, rejected the 20.1 m (66-foot) Denil (27.3 percent slope) at Bonneville Dam (footnote 2). It must be emphasized that these species often take up residence in main fishways at dams and may or may not be actively migrating during the summer. These observations imply only that those freshwater species which passed over the Denil fishways have the physical ability to do so.

American shad and Pacific lamprey are the only two anadromous nonsalmonid species which migrate up the Columbia River past the hydroelectric dams. During the observation period, American shad were abundant in the Columbia River to above McNary Dam and were beginning to appear at Little Goose Dam 112 km (70 miles) up the Snake River. Pacific lamprey were indigenous to the Snake River. Observations were made on the ability of these fish to pass over Denils of

varying length and slope. Several hundred shad were seen passing through a 7.9 m (26-foot) long Denil fishway inclined at slopes of 24 and 28.7 percent at Bonneville Dam and a 11.9 m (30-foot) long Denil with a 23.3 percent slope at McNary Dam. A few shad were seen passing through the 15.2 m (50-foot) long Denil (28.7 percent slope) at Little Goose Dam, but none passed through the 20.1 m (66-foot) long Denil (27.3 percent slope) used at Bonneville Dam. Pacific lamprey successfully passed through Denil fishways of all combinations of length and slopes used. Lampreys passed through the longest (20.1 m) Denil tested at a rate of up to 1,372 individuals in a 24-hour period (footnote 2).

Conclusions

Our observations indicate that American shad, common carp, chiselmouth, northern squawfish, Pacific lamprey, and suckers can ascend and pass through a Denil steeppass fishway of acceptable length and slope. The data also show that Denils ≥ 15 m long are unacceptable to common carp, and Denils >20 m long are unacceptable to northern squawfish, American shad, and suckers. Since migrating adult Pacific salmon, steelhead, and Pacific lamprey successfully pass through Denil fishways of up to 27 m in length, Denil ladders of selected lengths could be used, if desired, to pass salmonid fishes over small barriers, while denying upstream access to selected species of unwanted nonsalmonids, with the exception of Pacific lamprey.

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NMFS, NOAA Employees Earn Distinguished Awards

Six NMFS staff members were presented with awards for excellence and distinguished service from the U.S. Department of Commerce (Gold and Silver Medals) and NOAA (NOAA Administrator's Awards) in separate ceremonies late last year. In addition, 19 other NOAA employees were honored by the agencies.

Earning the Commerce Department's Gold Medal, the agency's highest honorary award for rare and distinguished contributions of major significance to the Department, the Nation, or the world, was Melvin W. Eklund, Supervisory Microbiologist with the NMFS Northwest and Alaska Fisheries Center's Utilization Research Division, Seattle, Wash. Eklund was honored for his 22 years of outstanding botulism research which have increased safety of fishery products, helped protect public health, and improved scientific knowledge of *Clostridium botulinum* (the bacteria responsible for botulism) and fish diseases.

His research team has discovered new types of *C. botulinum* and identified mechanisms controlling their toxin production, developed processes to increase the safety of smoked fishery products, and discovered liquid-smoke components that increase salt's inhibitory effects on *C. botulinum*. This work has saved millions of dollars in the salmonid industry. The research team's accomplishments are respected worldwide and have reflected positively on the NMFS.

Also earning the Gold Medal was Richard A. Severtson, Senior Special Agent with the NMFS Northwest Region's Law Enforcement Division. Reports the Commerce Department, "Agent Severtson contributed significantly to the protection of the U.S. fishery resources and to the fulfillment of U.S. Indian treaty obligations by exposing an entrenched cadre of professional poachers who were actively engaged in the theft and sale of thousands of Columbia River salmon and steelhead.

"For years these thieves had successfully avoided local detection and prosecution through an insidious scheme which disguised their criminal activity as a legitimate treaty-protected tribal fishing right. During the critical stages of the investigation, Agent Severtson, at great personal risk, directed and actively participated in the collection of numerous recorded conversations with armed criminal suspects. He also covertly photographed and documented these same individuals actively engaged in criminal conduct. Discovery of his law enforcement activities at any time, would have resulted in a life-threatening confrontation. In carrying out his assignment, Agent Severtson displayed uncommon courage and initiative which significantly benefitted the Pacific salmon resource and the law enforcement mission of the Department of Commerce."

Other NOAA Gold Medalists included Charles K. Townsend, Director, Pacific Marine Center, NOS, Seattle, Wash.; Ray E. Jensen, Director NWS Southern Region; and Steven W. Clark and James R. Smith, National Weather Service.

Receiving the Silver Medal, the Department's second highest honorary award for meritorious contributions of unusual value to the Department or the Nation, was Vaughn C. Anthony, Supervisory Fishery Biologist with the NMFS Northeast Fisheries Center. For almost a decade, Anthony has significantly improved the way scientists determine the abundance and productivity of fish populations. These assessments are critical to managing fish stocks important to the American fishing industry. Anthony improved communication with industry, led the work of many international committees and working groups, and published major scientific papers recognized as key references in his field. His contributions have significantly improved the management of fishery resources worth millions of dollars to the national economy.

Also receiving the Commerce Department's Silver Medal was Wilber R. Seidel and John W. Watson, Jr., for their significant contributions to conservation programs for threatened and endangered sea turtles. Seidel is Chief, Harvesting Systems and Surveys Division, and Watson is Chief, Branch of Harvesting Technology, NMFS Southeast Fisheries Center, Miami, Fla.

Seidel and Watson developed the Turtle Excluder Device (TED) which reduces the incidental capture of sea turtles in shrimp trawls by almost 100 percent. The device was developed through a 4-year research program involving major segments of the shrimp industry, environmental groups, and State and Federal fishery management agencies. It is the NMFS technical option to other management measures (i.e., area closures) to reduce the incidental mortality of sea turtles by commercial shrimp trawlers. The mortality of these animals is considered one of the two most serious environmental problems faced by the Service in the last decade.

Currently, over 200 devices are in voluntary use in the south Atlantic shrimp fishery, primarily because of ancillary benefits developed and demonstrated by the investigators, including increased shrimp catches and reduced bottom trash and marine organism bycatch. The device is being used by Indonesia to reduce a finfish bycatch problem in their shrimp fishery, and other countries are considering its adoption.

Other NOAA Silver Medal recipients include William J. Alder, NWS

Meterologist in Charge; John J. Carey, Director, NOAA Office of Budget and Finance; Malcolm Reid, NESDIS; Richard A. Snay, Michael W. Cline, and Edward L. Timmerman, NOS Geodesists; and Stanley A. Spivey, NWS Program Leader.

Earning the NOAA Administrator's Award was John G. Boreman, Jr., Fisheries Research Biologist with the NMFS Northeast Fisheries Center, Woods Hole, Mass. Boreman was cited for developing scientific information and serving as NOAA spokesman for conservation of east coast striped bass. Also honored by the NOAA Administrator was Frank I. Gonzalez, Oceanographer at the Pacific Marine Environmental Laboratory, Seattle, Wash., for outstanding research in coastal wave forecasting; and F. Lorraine Bodi, Attorney-Advisor with the Northwest Region's Office of the General Counsel, Seattle, for superior legal accomplishments in the area of fishery conservation and improvement. Others receiving the Award were Fernando Caracena, Jr., ERL; Richard C. Pryzwarty, NWS; Diana F. Lewis, NOS; Dennis K. Clark, NESDIS; and William E. Carter, NOS. And, receiving NOAA's Equal Employment Opportunity Award was Edward H. Young, Jr., with the Southern Region, NWS.

Awarded the NOAA 1983-1984 Unit Citation were the NMFS Northwest and Alaska Fisheries Center's Unaccountable Loss Program and the Staff of the Fishery Division, Beaufort Laboratory, NMFS Southeast Fisheries Center. Also receiving these citations were the NOAA Office of Policy and Planning; NOAA Officer Training Center Staff, Kings Point, N.Y.; NOS NOAA Ship *Peirce*—Atlantic Marine Center; NESDIS NGDC's Data Mapping Group and its Office of Research and Applications; and the following NWS units: Alaska Region Communications Computer System; Anchorage River Forecast Center, Alaska Region; California-Nevada RFC, Sacramento, Calif.; Cooperative Program Management Staff, NWS Headquarters; Marine Forecast Unit, WSFO San Francisco, Calif.; National Public Service Unit, National Severe Storms Forecast Center; Northeast River Forecast Center, Bloomfield, Conn.; Seattle Ocean Services Unit, January 1981 to June 1983; WSFO Albuquerque, N.M.; WSFO Topeka, Kan.; WSO Astoria, Oreg.; WSO Caribou, Maine; and WSO San Angelo, Tex.

Tagged Striped Marlin Recaptured Near Hawaii

A striped marlin, tagged by a sport fisherman off California in September 1983, was recaptured near Maui by a Hawaiian commercial longline fishing boat on 3 June 1984, according to Richard S. Shomura, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory.

The marlin, which weighed an estimated 130 pounds when it was tagged, was caught about 12 miles southeast of Santa Rosa Island off the coast of California by sport angler Richard E. Barrett, a member of the Balboa Angling Club of Newport Beach, California, on a sport fishing vessel operated by Captain Craig Oliver. It was recaptured on longline gear set less than 60 miles east of Maui by the local longline vessel *Typhoon* owned by Keith Colburn and operated by Captain Jim Carson. The marlin was at liberty about 9 months after release and traveled a straight-line distance of about 1,980 n.mi., or about 7 n.mi. per day, to the capture area. The fish weighed 135 pounds when it was recaptured.

Because it is not possible to determine the exact route a fish takes in traveling from point to point, fishery biologists consider the movement or migration of fish to be the shortest distance between the point of release and recapture. Shomura speculates that this striped marlin traveled more than the 1,980 total and 7 miles per day indicated by the incomplete information. The marlins are undoubtedly powerful swimmers like the tunas, and tunas are known to have covered sustained, longer daily distances in their migrations. For example, based again on a straight-line distance, a tagged bluefin tuna swam a distance of 4,830 miles across the Atlantic Ocean in 119 days, a sustained trip of 40 miles per day. Several other striped marlin have been recorded to make long-distance migrations. A fish tagged off the west coast of Mexico traveled 3,450 miles west (to the west of Hawaii), and several fish tagged off Mexico traveled south as far as 2,230 miles away.

The recently recaptured striped marlin was tagged as part of a cooperative Marine Game Fish Tagging Program and the Pacific Billfish Angler Survey supported by the NMFS Southwest Fisheries Center in La Jolla, Calif. Assistance is provided by organizations such as the International Game Fish Association, Ft. Lauderdale, Fla; National Coalition of Marine Conservation, San Deigo, Calif.; The Gardiner Foundation, Oakland, Calif.; and the Pacific Gamefish Foundation, Honolulu, Hawaii. Program Coordinator at the Center is Fishery Biologist Jim Squire.

In 1982, 776 striped marlin were tagged and released, mostly by sport fisherman, off southern California and Mexico. Striped marlin and other billfishes have also been tagged in other areas such as New Zealand, Hawaii, Australia, and in the central Pacific (by Japanese longline vessels).

Temporary Sea Scallop Management Standard Adjustment Extended

The National Marine Fisheries Service extended a temporary adjustment of sea scallop management standards on 1 October 1984 to allow fishermen to harvest scallops at a 35 average meat count (meat per pound), Richard H. Schaefer, Acting Director of the NMFS Northeast Region, announced. The extension may continue in effect through 30 September 1985. Fishermen who land sea scallops in the shell will be required to meet a 3 3/8-inch minimum shell height during the effective period of the adjustment.

Schaefer noted that he reached his decision to extend the temporary ad-

justment of the management standards following a review of available information about the condition of the resource and the status of management. Additionally, the extension will allow sufficient time to review and implement an amendment to the management program which was proposed by the New England Fishery Management Council. The amendment will eliminate the average meat count requirement and instead establish a minimum meat weight of 0.4 ounces (11.3 g), require shellstockers to comply with the meat weight standard, and make possession of sublegal scallop meats unlawful. The Council endorsed this extension at its August meeting. The extension was made under the authority of the fishery regulations, which allow adjustments and extensions of those adjustments if specified criteria are met. Schaefer's recommendation was predicated on the potential for inconsistencies between Canadian and U.S. sea scallop management standards which could have already adversely affected the U.S. fishery. In the absence of the extension, regulations implementing the U.S. sea scallop management program would, on 1 October 1984, have required fishermen to meet a 30 average meat count standard.

A Look at U.S. Seafood Users

The typical American fish eater is better educated, more urban, and better off financially than the average consumer. These are some of findings of marketing studies done by the National Marine Fisheries Service and the Canadian Department of Fisheries and Oceans.

Researchers recorded the eating habits of 7,500 American households throughout the country over a year, including when they served seafood, what kind they served, how they prepared it, and when they ordered seafood away from home. According to the study, those most likely to be big seafood eaters—the "high-use" consumers who make up 23 percent of the total population but account for 62 percent of all seafood consumption—are likely to be:

1) Big-City dwellers. Most of the heavy seafood users live in cities of over 500,000 population in California and the Mid-Atlantic, Great Lakes, and New England regions of the country.

2) Affluent and middled aged. The big fish eaters are overrepresented in professional and managerial occupations, are better educated, and tend to have fewer children than their counterparts who aren't such fish enthusiasts.

The study also shed some light on the dining habits of the average consumers, saying they eat seafood only 2.5 times a month, seldom plan a fish menu and preferring to serve seafood "just for a change," and hesitate to try new recipes when cooking fish or shellfish for their families. For further information contact B. G. Thompson, National Marine Fisheries Service, NOAA, Washington, DC 20235.

Monk Seals Moved to Johnston Atoll

The NOAA ship *Townsend Cromwell*, which completed the second leg on a four-leg research cruise in waters around the Northwestern Hawaiian Islands and Johnston Atoll in late 1984, met a NMFS Honolulu Laboratory field team on Laysan Island which, for 2 weeks, had been capturing adult male Hawaiian monk seals. The field team, led by Wildlife Biologist William G. Gilmartin, captured nine adult male seals which had been identified as participating in "mobbing," or collective attacks, on adult female and immature seals.

Such attacks have caused the death of several female seals the past 3 years, and the idea was to remove these male seals from the population so that one cause of female deaths would be reduced. This ploy has never been attempted before on the Hawaiian monk seal population, and is part of a major research effort to rehabilitate the endangered monk seals, said Gilmartin, who is leader of the monk seal research program at the Honolulu Laboratory.

The nine seals were loaded aboard the *Cromwell* and were transported 600 miles south to Johnston Island, where they were released and, it is hoped, will remain. Other Honolulu Laboratory personnel participating in the capture and transport of the seals were Wildlife Biologists Thea C. Johanos, Biological Technicians Alan K. H. Kam, Robert G. Forsyth, and Robert W. Morrow. Fishery Biologist Eugene T. Nitta of the Western Pacific Program Office, Southwest Region, NMFS, also participated in the operations, and Stan M. Minasian of the Marine Mammal Fund filmed the procedure.

Short-Finned Squid Resource Declines

The short-finned squid (*Illex*) is found in commercial quantities between Cape Hatteras and Newfoundland. This range represents the major distribution of a single stock. *Illex* undergo seasonal migrations onto the continental shelf during summer and off the edge of the shelf in winter to spawn. Results of recent larval and juvenile surveys indicate that spawning probably occurs south of Cape Hatteras in or near the Gulf Stream. Larvae and juveniles appear to be transported north and east by the Gulf Stream.

In some years, the spawning season is prolonged so that two broods (winter and late spring) are produced. These broods tend to vary in relative importance from year to year. *Illex* grow to a maximum length of about 114 inches (dorsal mantle length) and live about 12-24 months. Commercial catches off the United States are composed mainly of individuals from 4 to 11 inches which are probably from 8 to 24 months of age.

Catches and abundance of *Illex* have declined drastically in recent years throughout the Northwest Atlantic. The fishery in Canadian waters has virtually collapsed, with catches dropping from 153,000 metric tons (t) in 1979 to 408 t in 1983. Although the U.S. catch increased from about 300 t in 1980 to a record

9,900 t in 1983, the total international catch in U.S. waters was only 11,700 t in 1983, the lowest since 1971. The NMFS Northeast Fisheries Center autumn survey for *Illex* decreased 53 percent from 1982 to 1983 and was 85 percent below the 1967-1982 average. Prerecruit abundance in autumn 1983 was the lowest since 1970. Stock abundance off the U.S. coast declined from 21 million squid in 1982 to 10 million in 1983, the lowest level since 1974.

NE Party Boats Provide Valuable Fisheries Data

Voluntary data collection by party boat captains during their fishing trips provides fisheries scientists with valuable information, according to a report by the Northeast Fisheries Center (NEFC), Woods Hole, Mass. Party boats are vessels which provide anglers a day's fishing at offshore grounds for a nominal fee.

The report evaluates a pilot study conducted last September and October by the Interstate Party Boat Association of Gloucester, Mass., in cooperation with the NEFC. The captain of each party boat in the pilot study recorded data for each fishing trip on a one-page logbook form, then sent the logbook to the Center for statistical analysis. Data were provided on: 1) Area and time fished, 2) number of anglers aboard, 3) species, numbers, and sizes of fish caught; 4) presence or absence of gillnets in areas fished, 5) loss of fishing gear and time due to entanglement in gillnets, and 6) occurrence of gillnet marks observed on fish caught.

Center scientists find the data obtained from the logbooks helpful in a Center study of gillnetting along the Northeast coast. The Center began the study in response to a 1982 request by the New England Fishery Management Council for analysis of competition among trawlers, gillnetters, and party boaters for the same species in the same areas.

Fredric Serchuk, a senior assessment scientist for the Center, feels the voluntary logbooks "can provide the Center with—among other things—the types of data needed to document party boat/gillnet conflicts." He noted that the Center "cannot obtain such detailed data from its general surveys of marine recreational fisheries along the Northeast coast."

Allen E. Peterson, Jr., NEFC Director, lauded the cooperation of the party boat captains in the pilot study, and credited "much of the study's success to the close supervision and quality control performed by the Interstate Party Boat Association." Peterson added that the voluntary party boat logbook system is one of "a growing number of cooperative efforts between the Center and the region's recreational and commercial fishermen aimed at improving Center-fishermen relations and providing detailed data for better fisheries conservation and management." Anyone interested in receiving a copy of the report on the pilot study should write Fredric M. Serchuk, Northeast Fisheries Center, Woods Hole, MA 02543.

Lobster and Shrimp Tagging Programs

Year 2 of a planned 3-year joint Maine-NMFS Lobster Tagging Research Program began in July 1984. Operations, conducted from the NOAA Research Vessel *Gloria Michelle,* included the tagging and releasing of about 1,000 American lobsters in the Gulf of Maine.

Vinyl tubing back tags were used, the same as in 1983. Tag color is international orange and on the tag is imprinted the tag number B00001 (in consecutive order) and REWARD on one side and on the other side NMFS, WOODS HOLE, MA. The 1983 tags began with the letter A. Tagged lobsters should be returned to a National Marine Fisheries Service port agent as soon as possible for the reward.

Texas' sport and commercial shrimp fishermen have also been watching for black streamer tags attached to shrimp. Texas Parks and Wildlife Department officials reported tagging about 45,000 shrimp, and the National Marine Fisheries Service (NMFS) was to award up to $500 for certain tags randomly selected by computer. There were to be several contests for tag returns, each with a first-place award of $500, second-place $200, third-place $100, and fourth- through seventh-place, $50 each. The NMFS analyzed the data collected from tag returns and disbursed the awards.

U.S.-Japan Study Gulf Squid Resource

Japan and the United States cooperated in a research cruise in the northern Gulf of Mexico from 11 October to 16 November 1984 to survey squid resources in the Fishery Conservation zone, reports Richard J. Berry, Director of the NMFS Southeast Fisheries Center. The cruise was arranged through the office of Louisiana Congresman John Breaux with input from a large portion of the fisheries community in the Gulf.

Survey activities focused on assessing and mapping the distribution and abundance of offshore squid in the northern Gulf at depths of 240-1,800 feet. The research was conducted from the *Nisshin Maru No. 201,* a Japanese research trawler equipped with special squid trawling and jigging gear. Two scientists from the National Marine Fisheries Service and Louisiana State University were aboard the vessel during all survey operations.

Because commercial concentrations are less likely to be found in the fall months, subsequent cruises in the spring and fall have been encouraged. It is expected that this cooperative effort with Japan will provide valuable data for ultimately evaluating commercial fishing potentials for squid and biological and environmental data to support future scientific investigations. Full reports on the cooperative research effort will be provided through workshops and special news bulletins. For additional information contact either Andrew J. Kemmerer, Director, SEFC Mississippi Laboratories, NSTL Station, MS 39529 (601-688-3651) or John E. Greenfield, Assistant Director, NMFS Southeast Regional Office, 9450 Koger Boulevard, St. Petersburg, FL 33702 (813-893-3271).

World Salmon Farming Expected to Climb

The world production of pen-farmed salmon doubled during 1981-83. Of the 24,500 metric tons (t) of farmed salmon produced in 1983, almost 85 percent was Atlantic salmon, *Salmo salar* (Table 1). While the farming of Pacific salmon, *Oncorhynchus* spp., has also been increasing, the 1983 production accounted for only 15 percent of the total world production of pen-farmed salmon.

Salmon are farmed by two common methods. Cage culture involves rearing salmon in enclosures until they are ready for harvesting. The enclosures may be pens, cages, or tanks. Ocean ranching involves releasing immature salmon and harvesting the fish upon their return to the point of release. This report is primarily concerned with cage culture, where the harvest is predictable and can be done according to market demands.

The NMFS Branch of Foreign Fisheries Analysis projects that the production of pen-farmed Atlantic and Pacific salmon may exceed 100,000 t by 1990 (Table 1). Norwegian salmon farmers alone expect to produce 80,000 t of Atlantic salmon, but farmers in other countries also plan to increase their production significantly. These production estimates, however, depend on whether economic and environmental conditions will permit such expansion of salmon farming industries.

Norway is by far the most important producer of pen-farmed salmon. In 1983, the Norwegian production of farmed Atlantic salmon totaled over 17,000 t, or about 70 percent of the estimated world production. Japan is the second largest producer, but the entire 2,900 t of salmon farmed in 1983 was Pacific salmon for domestic consumption. The United Kingdom (Scotland), which produced 2,500 t of salmon in 1983, is the only country besides Norway with a large and successful Atlantic salmon farming industry. Production of pen-farmed salmon in other countries is not substantial, but continues to expand.

Norway

Norway is the world's most important producer of pen-farmed salmon. Their production in ocean cages has increased dramatically during the past decade, from only 170 t in 1973 to 17,000 t in 1983. During January-May 1984, Norwegian fish farmers produced almost 10,000 t of salmon, or 44 percent more than during the same period in 1983. If production continued to increase at the same rate, Norway would have produced an estimated 24,500 t of farmed salmon in 1984. Future production is also projected to increase to an estimated 50,000 t in 1986 and 80,000 t in 1990.

Norwegian production, however, will depend on several factors including the supply of smolts and competition from other countries which produce farmed salmon. Ironically, Norwegian companies have assisted many of these countries in establishing salmon farms because Norwegian Government regulations limit the size of salmon farms. Since the regulations do not allow the companies to expand operations in their own country, several Norwegian companies have exported their salmon farming technology to other countries where favorable environmental conditions or potential markets exist.

Farmed salmon has become an important Norwegian fishery export. In 1983, Norway exported 15,500 t of farmed salmon, or over 90 percent of its production. During 1982-83, Norwegian farmed salmon exports increased from 9,400 t to 15,500 t, or by 4 percent (Table 2). Observers believe that the salmon exports increased because of the high quality of the fish and its year-round availability.

The Norwegian Government is actively assisting and regulating the salmon farming industry. The Government assists small-scale farmers by guaranteeing loans through the Regional Development Fund and the Agricultural Develop-

Table 1.—World production of pen-farmed salmon, 1981-83 and 1990 projections.

Species and nation	Salmon production (t) 1981	1982	1983	1990
Atlantic salmon				
Norway	8,907	10,266	17,016	80,000
United Kingdom	1,000	2,100	2,500	8,500
Ireland	80[1]	103	256	2,000
Canada	35	140	180[1]	1,000
Faroe Islands	100[1]	130	160	2,000
Sweden	60[1]	80[1]	100[1]	500
Iceland[2]	20[1]	30	50	300
Finland	30	30	30	200
France	2[1]	5[1]	10[1]	30
Subtotal	10,234[1]	12,884[1]	20,302[1]	94,530
Pacific salmon				
Japan	1,150	2,122	2,900	8,000
United States	450[1]	680[1]	900[1]	1,800
Canada	176	400[1]	129[1]	450
Chile	60	80	100	3,000
France	60	80	80	500
New Zealand	2[1]	5[1]	10[1]	50
Subtotal	1,898[1]	3,392[1]	4,119[1]	12,800
Grand total[1]	12,132	16,276	24,421	107,330

[1] NMFS estimates.
[2] Includes ocean ranching.

Table 2.—Norwegian exports of farmed salmon, by country, 1982-83.

Country	Exports (t) 1982	1983	Change (%)
France	2,710	4,293	+ 59
United States	930	2,486	+ 167
Germany (FRG)	1,850	2,466	+ 33
Denmark	1,240	1,957	+ 58
United Kingdom	930	1,381	+ 48
Sweden	590	824	+ 40
Belgium	370	558	+ 51
Switzerland	350	504	+ 44
Spain	270	453	+ 68
Netherlands	120	182	+ 52
Japan	40	134	+ 235
Finland	140	127	– 9
Other	40	94	+ 135
Total	9,412	15,464	+ 64

Source: Royal Norwegian Embassy, Washington, D.C., 1984.

ment Fund. The Government also provides funds to research institutes studying salmon farming methods and reportedly pays a $0.50/kg subsidy to airlines for shipping fresh farmed salmon.

The Norwegian Government regulates salmon farming by limiting the maximum size of fish farms. As a result, most Norwegian salmon farms are small; the average annual production of the 301 salmon farms (rainbow trout, *S. gairdneri,* was also produced by 122 of the salmon farms) operating in 1983 was 57 t (Table 3). This policy is intended to ensure that small-scale fish farmers can make a living. Additionally, the many small-scale salmon farming operations maintain an industry and a population in previously underpopulated coastal regions.

Table 3.—Number of Norwegian salmon farms and production, 1975–83.

Year	Number of farms: Salmon only	Number of farms: Salmon/trout	Production (t)
1975	18	27	862
1976	33	28	1,431
1977	53	31	2,137
1978	65	51	3,540
1979	72	75	4,389
1980	91	82	4,312
1981	97	118	8,907
1982	136	127	10,266
1983	179	122	17,016

Source: Norwegian Central Bureau of Statistics.

Table 4.—U.K. farmed Atlantic salmon production, 1975–1990.

Year	Quantity (t)	Year	Quantity (t)
1975	200[1]	1983	2,536
1976	400[1]	1984	4,000[2]
1977	400[1]	1985	4,300[2]
1978	450[1]	1986	5,300[2]
1979	520	1987	6,000[2]
1980	598	1988	6,500[2]
1981	1,333	1989	7,500[2]
1982	2,152	1990	8,500[2]

[1] Estimated.
[2] NMFS projection.
Sources: Highlands and Islands Development Board (1975–79 estimates); Department of Agriculture and Fisheries for Scotland (1979–83 data).

Japan

Japan farms only Pacific salmon in ocean cages. Japanese pen farming of salmon began in 1973, when 1 million coho salmon, *O. kisutch,* eggs were imported from the United States for freshwater culture. In 1975, the Japanese switched to marine pen-farming because the salmon grew faster in the ocean.

The Japanese production of pen-farmed cohos has increased from 72 t in 1978 to 2,900 t in 1983. Japanese companies are expected to produce 4,500 t of farmed salmon in 1984 and as much as 8,000 t in 1990. The Nichiro[1] company produced about half of the estimated 1984 production (2,500 t), followed by Taiyo (1,000 t), Nichimo (500 t), and other smaller companies (500 t). Currently, the entire production is consumed domestically and the farmed coho salmon does not compete with Japanese salmon imports from the United States, which are mainly sockeye salmon, *O. nerka.* While future increases in Japanese production are not expected to be exported, salmon farming may eventually reduce Japanese salmon imports, the majority of which come from the United States. The Japanese Government does not offer financial incentives to salmon farmers.

United Kingdom

The United Kingdom (U.K.) is the only country outside Norway with a large and commercially successful Atlantic salmon farming industry. All U.K. salmon farming is located in Scotland, mostly in the protected fjord-like regions of the Western Isles and off the northwestern coast. Most salmon is farmed by large companies such as Marine Harvest and Golden Sea Products. Other important producers are McConnell Salmon, Joseph Johnson, Wester Ross, and Lancatch. Many small-scale salmon farms have also started commercial production in the past few years. Farmed salmon production has increased rapidly from only 600 t in 1980 to 2,500 t in 1983 (Table 4). Scottish officials are projecting that production will be about 4,000 t in 1984. Since there is a limited number of suitable sites, the production of farmed salmon is not expected to exceed 8,500 t in 1990.

The Scottish salmon farming industry could eventually expand its production beyond 8,500 t if projects on the more isolated islands prove successful, or if onshore tank culture becomes more profitable. The few tank farms currently operating have been only marginally profitable, but some observers believe that the expansion of the Scottish salmon industry depends on the future success of these onshore projects.

The British Government provides little assistance to the salmon farms apart from regional development subsidy programs, which together with European Community (EC) assistance, have provided some start-up and working capital. While the Government does have some authority over fish farming (primarily to control fish diseases), there are no regulations preventing large corporations or foreign investors from operating a salmon farm. As a result, many Norwegian companies are playing an increasingly active role in the Scottish salmon industry.

Ireland

Ireland produces farmed Atlantic salmon by ranching and ocean cage methods. In 1983, Ireland produced 256 t of pen-farmed salmon, much of which was marketed in the United Kingdom. Several state-sponsored and private organizations are beginning salmon culture projects. The Irish Government granted the Salmon Research Trust of Ireland nearly $50,000 in 1984 for studies which included the selective breeding of salmonids. The Irish Government does not, however, provide special incentives for salmon farming.

Canada

Canada is developing salmon ranching and cage farming to aug-

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

ment both its Atlantic and Pacific salmon catch. Most Canadian ocean cage farming of Atlantic salmon is in the province of New Brunswick, where 140 t was produced in 1982, a 300 percent increase over the 35 t farmed in 1981. Some observers believe that cold water temperatures along the Canadian Atlantic coast limit the potential for farming salmon.

Since 1975, cage-farmed Pacific salmon (pan-sized chinook, *O. tshawytscha,* and coho) have been produced in British Columbia. In 1983, production amounted to 129 t, less than 1981 and 1982 when 176 t and 425 t, respectively, were produced. Only 7 of the 14 salmon farms operating in British Columbia during April 1983-March 1984 reported any production, and one farm alone accounted for more than 50 percent of the total production of farmed Pacific salmon.

The Canadian Government apparently does not offer special incentives for cage farming, but does encourage private initiative in salmon culture. Canadian salmon farmers, however, have had problems obtaining sufficient quantities of smolts. In 1982, only 10 percent of the small 1982 smolt production was earmarked for salmon farmers; the rest was used by Government for salmon enhancement. A Norwegian company announced in 1984 that it plans to build a large smolt hatchery in New Brunswick that will produce 500,000 smolts by 1987.

Denmark (Faroe Islands)

Salmon farming in the Faroe Islands has grown considerably since it first began in 1980. Total production of pen-raised Atlantic salmon was 130 t in 1982 and 160 t in 1983. Marine farm production of Atlantic salmon is expected to approach 1,700 t by 1987. According to some reports, if hatcheries can supply more smolts, Faroese production could be substantially more than the projection.

The Faroese Home Rule Government strongly supports the export potential of salmon by providing technical assistance and giving investment loans to fish farmers. These preferential loans, provided by the Faroese Industrial Development Fund, are usually given for 10 years with a 2-year grace period and may cover up to 85 percent of the investment. The Government, concerned about the effects of marine fish farming on the environment, strictly regulates salmon cage farming.

Sweden

Sweden produced an estimated 100 t of pre-farmed Atlantic salmon in 1983. Most of the farmed salmon is cultured in the warmer waters off southern Sweden. No information is available on the Swedish Government's assistance to the salmon farming industry.

Chile

Chilean salmon farmers are attempting both ocean cage culture and ranching. Ocean ranching has achieved only marginal results, but the production of pen-farmed salmon is steadily increasing. The pen-raised salmon is produced primarily by two aquaculture development projects, one Japanese and the other U.S.-Chilean. The Canadian International Development Research Center is also studying a possible salmon culture project in Chile.

The production of farmed salmon in Chile increased from 80 t in 1982 to 100 t in 1983. A major feeding error, however, resulted in the loss of about 200 t of fish from the 1983 projected production of 300 t. Chilean salmon farmers estimate that by 1990, production may be as high as 3,000 t.

Chilean salmon farmers plan to market most of their production in the United States and Europe. Some Chilean growers believe that they will be able to profitably deliver fresh salmon to the U.S. market for $3.00-$3.50/kg. Because of the reversed seasons in the Southern Hemisphere, Chile will be able to supply fresh Pacific salmon to northern markets when fresh Pacific salmon is not available in the United States. The Chilean Government reportedly does not provide financial incentives for salmon farming.

France

France has been experimenting with ocean cage farming of coho salmon with the assistance of the U.S. Government (NMFS). The project, however, has not been successful in establishing a commercially feasible operation. The estimated production of farmed salmon in France during 1983 was about 80 t. By 1990, the annual production of farmed salmon may amount to 500 t.

The French are also experimenting with farming Atlantic salmon off Canada (St. Pierre and Miquelon) and in the Southern Indian Ocean (Kerguelen Islands). The salmon projects are supported by The French Scientific and Technical Institute of Ocean Fisheries (ISTPM), and are also eligible for subsidies from the European Community.

Iceland

Iceland's small farmed Atlantic salmon production, primarily from ocean ranching, is still in an experimental stage. Ocean cage farming has not been successful because Iceland lacks sufficiently protected fjords, and water temperatures are too cold during the winter. Icelandic scientists are nonetheless continuing efforts to develop the pen farming of Atlantic salmon. Icelandic salmon ranching, however, is expanding and may contribute significantly to future fishery exports. Salmon production by cage farming and ranching increased from 30 t in 1982 to 50 t in 1983. The Icelandic Government projects that the 1984 production will exceed 100 t.

Two companies are currently farming salmon in Iceland. The Icelandic-Norwegian joint venture company (ISNO), which operates Iceland's largest salmon farm, expects to produce about 35 t of farmed salmon in 1984. A U.S. salmon farming company, in a joint venture with an Icelandic investment company, plans to eventually produce 2,100 t of pen-farmed salmon annually in Iceland. The Icelandic Government operates some 40 salmon hatcheries and research stations, but does not provide

financial incentives to salmon farmers.

Finland

Finland's pen-farmed salmonid production is mainly rainbow trout, but some Atlantic salmon is also farmed. Currently only 30 t of farmed salmon is produced annually, but observers believe that Finnish production will increase. Salmon farmers receive no special financial incentives from the Finnish Government. Some salmon farms, however, in the so-called "developing areas" on the northern and northeastern coasts, receive grants and low-interest loans to help cover the high transportation costs.

New Zealand

The New Zealand salmon farming industry is still in the beginning stages. Since commercial fishing for wild salmon is illegal, the New Zealand salmon industry relies exclusively on Pacific salmon produced by ranching and cage farming. Salmon production statistics are not available, but New Zealand trade data show an export of about 7 t of salmon in 1983, of which the United States imported almost 90 percent (6 t).

The Government of New Zealand recently ended restrictive regulations on ocean farming to permit the further expansion of the salmon farming industry. The Government, however, does not provide any special assistance or incentives to prospective salmon farmers. Because salmon farming is considered a "new" industry in New Zealand, salmon farmers receive the same special tax benefits afforded to all new industries.

Australia

Salmon farming experiments in Australia have been successful and a commercial industry is expected shortly. Projects for ocean cage farming of Pacific salmon (chinook) in Victoria and of Atlantic salmon in Tasmania were underway in 1984. The Australian Government tightened regulations for imports of fresh salmon in September 1983 to reduce the risk of disease in salmon farms. Most of the technology for the Australian salmon farms has been supplied by other countries. According to press reports, a Norwegian company will sign a contract with the Australian Government in the fall of 1984 to farm trout and salmon in Tasmania. The company intends to process the salmon produced according to the high quality standards followed in Norway. (Source: IFR-84/89B.)

Iceland's Fishing Imports and Exports

Iceland depends on its fishing industry for a healthy economy since fishery products account for almost 75 percent of its total exports. In 1983, however, the fishing industry faced severe problems such as declining fish stocks, rising operating costs, stagnant prices, as well as increased competition in important export markets. Even though the Icelandic fisheries catch increased from 783,000 metric tons (t) to 819,000 t during 1982-83, the ex-vessel value of the catch decreased from $274 million to only $240 million.

Cod has traditionally been Iceland's most important species, but the catch in 1983 was the smallest since 1948. While the 1983 cod quota was set at 300,000 t, Icelandic fishermen landed only 290,000 tons. The Icelandic capelin fishery was allowed to resume in October 1983 after a 1-year suspension. The increasing capelin catch, however, will not make up for the decreasing cod catch because the value of capelin landings is estimated at only one-tenth that of cod (per unit weight).

Iceland's fishery exports increased in value during 1983 mainly because production was switched from salted and dried fish to higher valued frozen products. Exports of frozen fish in 1983 were valued at $307 million compared with $256 million in 1982. The U.S. continued to be Iceland's most important export market for fishery products. In 1983, Iceland exported $196 million worth of fishery products to the U.S. (mostly frozen fillets and blocks), or 38 percent of Iceland's total fishery exports.

The National Technical Information Service has made available a report on the Icelandic fishing industry in 1983. The 10-page report, prepared by the U.S. Embassy in Reykjavik, includes statistical tables on catch and fisheries trade. U.S. companies can obtain a copy of this report for $7.00 by requesting report number PB-84-245208 ("The Icelandic Fishery: 1983 Report and 1984 Outlook") from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. (Source: IFR-84/72-NTIS.)

Panama's Fishing Industry Reviewed

The Panamanian fishing industry rebounded strongly in 1983, as a result of a sharp increase in the anchovy catch. Over 142,000 metric tons (t) of fish and shellfish were landed in 1983, doubling the 1982 catch. Shrimp is Panama's most important fishery and the country's second most important export commodity. The shrimp catch declined slightly in 1983. Many observers believe that shrimp culture will enable Panama to increase its shrimp production substantially. The shrimp industry is expanding and the Government estimates that the area of shrimp ponds may double by 1987.

The U.S. Embassy in Panama has prepared a 42-page report on the Panamanian fishing industry. The report reviews the shrimp industry (both the trawler fishery and pond culture), fish aquaculture, artisanal fishing, and the trout, anchovy, herring, shark, and tuna fisheries. Statistical appendices and lists of government fishery organizations, international organizations, fishery associations, fishing companies, shipyards, and marine equipment suppliers are also included. A copy can be obtained by ordering report number PB-85-100972 from NTIS, Springfield, VA 22161 for $8.50. (Source: IFR-84/76 NTIS.)

Peru, Belize Promote Culture of Shrimp

Peru and Belize have some of the smallest shrimp fisheries in South and Central America, respectively (Table 1). However, several projects are underway in both nations which could greatly expand their culture and the export of shrimp.

Table 1.—Shrimp catch in South and Central America, 1982[1].

Country	Catch (t)	Country	Catch (t)
Brazil	47,530[2]	Chile	3,450
Ecuador	29,500	El Salvador	3,217
Panama	14,732	Honduras	2,686
Argentina	7,814	Nicaragua	2,655
Colombia	6,026	Guatemala	2,490
Venezuela	4,747	Costa Rica	2,270
Guyana	4,005	Peru	460[4]
Surinam	3,997[3]	Belize	100[2]

[1] Source: FAO "Yearbook of Fishery Statistics, 1982."
[2] FAO estimate.
[3] Data for 1981.
[4] Probably does not include cultured shrimp.

Peruvian Shrimp Development

Peru is currently developing a shrimp culture industry that will enable it to substantially increase production. Almost all of Peru's shrimp culture takes place in the northern province of Tumbes which borders Ecuador, and the species cultured are almost entirely *Penaeus vannamei* and *P. stylirostris.*

Peruvian shrimp culture began in the middle 1970s. One of the leading investment groups to enter the industry was Inversiones Nueva York[1] (INY) which began operations in 1977. INY currently includes six companies which operate 650 hectares of ponds in the La Cruz District of Tumbes Province. INY also operates a processing plant with two plate freezers and one freezing tunnel which, combined, can freeze about 11 metric tons (t) of shrimp in an 8-hour shift. INY exported its first shrimp in 1979, a $0.3 million shipment to New York, but increased shipments to $3.2 million by 1982.

Expansion

The Peruvian shrimp culture industry had expanded to about 30 companies by 1983. Most companies are small and only operate about 20-30 hectares of ponds, but a few, like INY, are substantially larger. One estimate by Alejandro Bermejo, editor of Peru's fisheries magazine *Pesca,* suggests that in 1983 there were less than 1,500 hectares of ponds in the entire country. Another more recent estimate by the Ministry of Fisheries suggests that there were about 2,000 hectares of ponds in Peru as of early 1984. Data is not available on actual production, but Bermejo estimates that most operators are achieving yields of at least 1 t of shrimp per year for each hectare of pond which would mean that Peru is currently culturing about 1,500-2,000 t of shrimp per year.

Peruvian shrimp culturists face two problems. The most immediate problem, limiting the growth of the country's shrimp culture industry, is a reliable, year-round source of postlarvae. There are no shrimp hatcheries in Peru. All postlarvae used for stocking are collected in the mangrove swamps by artisanal fishermen. As a result, the supply of post larvae is erratic. The availability of postlarvae is seasonal, following the natural life cycles of the shrimp, and the artisanal fishermen cannot distinguish between shrimp species. *P. vannamei* is generally preferred by the pond operators, but the postlarvae delivered to the pond operators are a mixture of species. Studies of the life cycles of the various species, especially *P. vannamei* and *P. stylirostris* could help the fishermen to adjust their gathering practices so as to collect larger proportions of the desired species. The Government, however, has not yet conducted such studies. A longer term problem is the destruction of the country's mangroves to build ponds and for other purposes. Peruvian authorities, however, do share the concern of Ecuadorean officials over the gradual destruction of the mangroves.

Damage

Peru's shrimp culture industry was severely damaged in 1983 by the flooding which accompanied the 1982-83 El Niño event. Northern Peru was hit by some of the worst floods in the country's history. The serious flooding began in January and, as a result, pond operators could not resume operations until July. Not only were many ponds damaged, but the destruction of roads and bridges brought transportation in Tumbes Province to a standstill. Most companies did not resume exporting until November. Some observers were concerned that the ponds would be impaired for years because of the large quantity of silt and vegetable matter which was washed into them. The same situation reportedly affected the operations of some Ecuadorean ponds. The Peruvians claim, however, that to avoid such problems they contracted a Japanese consultant, and as a result of his suggestions, the ponds are reportedly now functioning better than before the floods.

The Peruvian Government through the Banco Industrial de Peru (BIP) and the Peruvian Development Corporation (COFIDE) have helped pond operators to obtain credits for initial operations. Investors are now asking for additional credits. Local pond operators estimate that 4,000-8,000 hectares of ponds could be built in northern Peru. Industry sources estimate that it costs about

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR), Language Services Biweekly (LSB) reports, or Language Services News Briefs (LSNB) produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

[1] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

$0.25 million per 100 hectares to build ponds. As a result, an additional $10-20 million are needed to fully develop the area's potential. INY Managing Director, Eduardo Gonzalez, estimates that such an investment could eventually bring Peru $8 million annually in additional export earnings. Other observers believe that export earnings could eventually exceed $15 million. Given Peru's difficult financial situation, however, Government assistance is hard to obtain.

Peruvian Exports

Shrimp culture has enabled Peru to increase its shrimp exports in recent years. U.S. import statistics show an unrealistically large increase, from only $0.9 million in 1977 to $35.9 million in 1983 (Fig. 1). This data, however, is misleading. No data is available just for cultured shrimp. U.S. imports include shrimp caught by Peruvian trawler fishermen and shrimp smuggled in from Ecuador to avoid that country's export regulations. Unconfirmed reports suggest that most of the sharp 1983 increase was due to the excellent year experienced by the trawler fishermen and the illegal shipments from Ecuador. These unconfirmed Peruvian reports are probably accurate as the extensive coastal flooding must have caused the production and export of cultured shrimp to have declined in 1983. Recent reports from Peru, however, suggest that the exports of cutured shrimp will increase in 1984. One estimate suggests that about 1,800 t of shrimp worth about $15 million will be exported in 1984. (Source: IFR-84/39.)

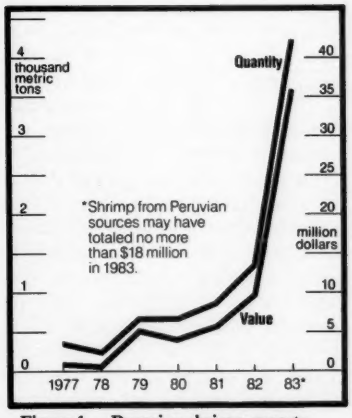

Figure 1.—Peruvian shrimp exports to the United States, 1977-83. Peruvian observers report that the value of shrimp from strictly Peruvian sources, cultured and trawler caught, probably totalled no more than $18 million in 1983.

Belizian Shrimp Culture

Belize has the smallest shrimp fishery in Central America (Table 1), with a 1982 harvest of only about 100 t. Some observers believe, however, that the country has the potential to culture sizeable quantities of shrimp, and several projects are underway which could make Belize an important Central American shrimp producer by 1990.

Five groups are currently involved with shrimp culture projects in Belize: Two projects are under construction, two other groups have finalized their plans but are seeking financing, and the remaining project is in the planning stage. The pond operators have not yet cultured any sizeable quantities of shrimp. One of the operators, however, produced about 2.2 t (whole weight) of shrimp in 1983 on 3 hectares of ponds as a pilot project. The shrimp was marketed locally, but because of personnel changes, those ponds have not been used in 1984. There were no exports of cultured shrimp in 1983 and such shipments are unlikely in 1984. Two pond operators plan to begin production in 1984 and hope to begin exporting by 1985. Pond operators are culturing *Penaeus vannamei* and *P. stylirostris*, the same species that are cultured in Ecuador and Peru. Recent reports from Belize indicate that *P. monodon* is being tried. Most operators also plan to experiment with *P. schmitti*, but it may be some time before those trials are conducted.

Pond Construction

One project, under construction near Belize City, will include a hatchery with the capacity of producing over 50 million postlarvae per year in 40 hectares of ponds. Eventually, they plan to build about 400 hectares of ponds, sell postlarvae in the United States, and produce about 70 t of shrimp tails by 1985.

General Shrimp Ltd., managed by John R. Snell, is currently constructing 120 hectares of ponds. General Shrimp also plans a hatchery which, however, may not be capable of fully stocking all the ponds the company plans to build. Snell hopes to produce about 580 t of shrimp per year, but some local observers believe 250 t per year is more likely.

Silver Creek Shrimp Farms, directed by Russ Allen, hopes to begin constructing 200 hectares of ponds at Independence in Stann Creek District by September 1984, and to begin production by 1985. Allen and his partners hope to harvest about 225 t of shrimp in 1985, and rapidly expand production thereafter.

Shrimp Feed

Domestically milled shrimp feed is not yet available in Belize. Feed is currently being imported from the United States and Honduras. A mill for livestock feed is under construction. If Belize's shrimp culture industry expands as expected, the new mill may eventually also produce shrimp feed.

Pond operators do not yet know what yields they will be able to achieve in Belize. Most believe that they will be able to produce 2-3 crops per year and, initially, achieve yields of 0.1-0.2 t of shrimp per hectare for each crop. Most plan to produce primarily mid-sized shrimp (Fig. 2).

Industry Expansion

The rate at which the industry will develop is unclear. The Belizian shrimp culture industry is now limited by a shortage of postlarvae to stock the ponds. The key to the development of the industry will be the production of postlarvae in hatcheries. Once there are operational hatcheries in the country, the industry could expand rapidly. The number of individuals, however, with the necessary

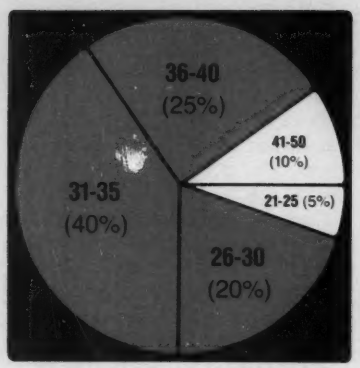

Figure 2.—Projected proportions of Belizian shrimp production (shrimp per pound).

Table 2.—Projected area of Belizian shrimp ponds, 1985-89.

Project	Pond area (hectares)				
	1985	1986	1987	1988	1989
Bowen & Allen	200	200	400	800	1,200
Zabanch & Allen	80	200	200	400	800
Jackson	40	140	200	300	400
Snell	120	120	200	300	400
Crosby		200	200	400	400
Others	40	80	400	2,000	4,000
Total	480	940	1,600	4,200	7,200

[1] Source: NMFS Branch of Foreign Fisheries Analysis estimates.

expertise to operate a modern shrimp hatchery, is limited. It is not yet clear whether Belize will be able to attract such individuals. Without hatcheries to supply postlarvae, the growth of the industry will be severely restricted.

Belize does appear to have considerable land which could be devoted to shrimp culture. One estimate suggests that there are over 40,000 hectares of land which could be used for shrimp culture. Belize does have one major disadvantage when compared with shrimp culture operations in Ecuador. The tidal range is only about 0.3 to 0.5 m which will mean that considerable quantities of water will have to be pumped. Other basic data such as soil suitability, availability of freshwater, predation, roads, and infrastructure are not readily available. The companies involved in Belize, however, believe that conditions will support viable commercial operations, but that it could take up to 20 years to fully develop the country's potential.

Companies are beginning to build ponds and it has been projected that there may be as many as 7,200 hectares of ponds in production by 1989 (Table 2). Some optimistic local observers believe that production of cultured shrimp could reach 20,000 t by 1989. At least some of the investors currently proceeding with shrimp culture projects believe that they have solved most of the serious technical problems. The difficulties associated with pond building and beginning production in such a large number of new ponds, however, suggest that production will not reach optimal levels during the first few years. It is also unlikely that an adequate number of postlarvae will be available to stock such a large number of ponds.

As a result, while the large number of variables involved makes projecting future production levels difficult, the NMFS Branch of Foreign Fisheries Analysis believes that production is not likely to exceed about 10,000 t by 1990. This would still be a massive increase over the projected 1985 and 1986 production (400 and 1,000 t, respectively) of Belize's small shrimp fishery and would also make the country one of Central America's major shrimp producers. In addition, such production would be achieved using only a small part of the 40,000 hectares potentially available for shrimp culture. (Source: IFR-84/46.)

Mexico Hikes Fines for Illegal Foreign Fishing

The Mexican Government has begun assessing sharply increased fines to foreign fishermen arrested for fishing in Mexico's 200-mile Exclusive Economic Zone (EEZ) without a valid license. The Government has fined foreign fishermen up to 2.5 million pesos ($12,500) for repeated offenses.

Mexican newspapers reported in late 1984 that the U.S. shrimp trawler *BBC* was to be fined 2.5 million pesos. The *BBC* was seized 10 October about 4 miles south of the U.S.-Mexican marine border. The newspapers claimed that the Mexican Government assessed the unusually heavy fine because the *BBC* had been previously seized and fined.

The vessel's owner contended that the *BBC* should not have been charged as a repeat offender because a different owner operated the vessel when it was seized in June. The Mexican Government contended that the owners of seized U.S. shrimp trawlers often make paper changes in ownership after their vessels are released. As a result, Mexican officials intend to apply the higher repeat-offender fines if a vessel was previously seized, regardless of the vessel name or identify of the owner.

The Secretariat of Fisheries (SEPESCA) has recommended that the total of all previous fines be doubled when foreign vessels are seized three or more times in the EEZ. SEPESCA is trying to dissuade U.S. fishermen from shrimping in Mexican waters, but would like to avoid the more drastic measure of confiscating the vessels. In the *BBC* case, the Government decided to fine the *BBC* 2.4 million pesos. The fine is double the 1.2 million pesos that the *BBC* was fined after being seized in June.

The Mexican Navy subsequently announced plans to increase surveillance activity off the state of Tamaulipas. Vice Admiral Hector Argudin Estrada told reporters on 8 November that the Navy will redouble efforts to seize U.S. shrimp trawlers off Tamaulipas. Argudin also stated that so far in 1984, the Navy has seized about the same number of U.S. trawlers as in 1983. This statement came as a surprise to some observers. While the Navy has not released a list of seized vessels, only a small number of seizures has been reported by the Mexican press in 1984. During 1983, the press reported the seizure of 68 U.S. shrimp trawlers. (Source: IFR-84/94.)

New NMFS Scientific Reports Published

The publications listed below may be obtained from either the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, or from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Writing to the agency prior to ordering is advisable to determine availability and price, where appropriate (prices may change and prepayment is required).

NOAA Technical Report NMFS 10 Sindermann, Carl J. (editor). **"Proceedings of the Seventh U.S.-Japan Meeting on Aquaculture, Marine Finfish Culture, Tokyo, Japan, October 3-4, 1978."** August 1984, 31 p. (6 papers.)

NOAA Technical Report NMFS 11. Upton, Steve J., David W. Reducker, William L. Current, and Donald W. Duszynski. **"Taxonomy of North American fish Eimeriidae."** August 1984, 18 p., 30 figs.

ABSTRACT

Taxonomic descriptions, line drawings, and references are given for the 30 named and 5 unnamed species of North American fish Eimeriidae. In addition, a key was developed based on available morphologic data to distinguish between similar species. Taxa are divided into two genera: *Eimeria* (27 species) which are tetrasporocystic with dizoic, nonbivalved sporocysts, and *Goussia* (3 species) which are tetraporocystic with dizoic, bivalved sporocysts that lack Stieda bodies and have sporocyst walls composed of two longitudinal valves.

NOAA Technical Report NMFS 12. Fay, Francis H., and Gennadii A. Fedoseev (editors). **"Soviet-American cooperative research on marine mammals. Volume 1—Pinnipeds."** September 1984, 104 p. (12 papers.)

NOAA Technical Report NMFS 13. Coe, James M., David B. Holts, and Richard W. Butler. **"Guidelines for reducing porpoise mortality in tuna purse seining."** September 1984, 16 p., 20 figs., 4 tables.

ABSTRACT

More than a decade has passed since the passage of the Marine Mammal Protection Act of 1972. During that time the U.S. tuna purse seine fleet reduced its incidental

Decapod Crustaceans of the U.S. Atlantic Coast

"Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida," by Austin B. Williams, has been published by the Smithsonian Institution Press, 955 L'Enfant Plaza, Suite 2100, Washington, DC 20560. The author is with the NMFS Systematics Laboratory at the National Museum of Natural History, Smithsonian Instutition, Washington, DC 20560.

This new volume is a revised and extended version of the author's 1965 report "Marine Decapod Crustaceans of the Carolinas," Fish. Bull. 65(1):1-298, which itself was a revision of the first definitive handbook on marine decapod crustaceans of southeastern North America by William Perry Hay and Clarence A. Shore published in 1918 as "The Decapod Crustaceans of Beaufort, N.C., and the Surrounding Region," Bull. U.S. Bur. Fish, 35:369-475.

This latest volume is a well illustrated compilation of data on the identification, distribution, life history, and ecology of the decapod crustaceans found along the continental shelf of the eastern United States. Included is a discussion of the history of decapod crustacean studies in the region, classification of the group, its zoogeograhic relationships, details on study materials, and species accounts.

Altogether, 342 species are treated, with ranges from the heads of estuaries to the 100-fathom (190 m) contours. Thus, no deep-sea or freshwater species are included. Notes are given for 14 extralimital species having doubtful position in the regional fauna.

The text begins with a general key to the region's suborders, infraorders, sections, superfamilies, and families. This is followed by family, subfamily, generic, and specific accounts. Additional keys to categories below family are arranged through the text. Excellent species accounts include abbreviated synonymy, recognition characters, measurements, appropriate figures, coloration, variation (if any), habitat data, type-localities, known range, and remarks. Some of the "Remarks" are necesarily very brief, but many are quite extensive and provide fine summaries of life history and ecological data. Included are references to much of the critical literature up to about 1980.

A number of these shrimps, lobsters, and crabs constitute some of the most valuable of the U.S. fisheries. Many others play important roles in their marine environments, and continued studies of them and their ecological relationships are important, and this book will serve as an excellent and very valuable reference. Indexed, the 550-page hardbound volume includes a glossary and is available from the publisher for $40.00.

porpoise mortality rate more than ten fold. This was made possible through the development of gear and techniques aimed at reducing the frequency of many low probability events that contribute to the kill.

Porpoise are killed by becoming entangled or entrapped in folds and canopies of the net and suffocating. The configuration of the net, both before and during the backdown release procedure, is a major determinant of the number of porpoise killed. Speedboats can be used to tow on the corkline to prevent net collapse and also to adjust the net configuration to reduce net canopies prior to backdown. Deepening a net can reduce the probability of porpoise being killed by prebackdown net collapse. The effects of environmental conditions and mechanical failures on net configuration can result in high porpoise mortality unless mitigated by skilled vessel maneuvers or prevented by the timely use of speedboats to adjust the net.

The backdown procedure is the only means to effectively release captured porpoise from a purse seine. It is also the time during the set when most of the mortality occurs. The use of small mesh safety panels and aprons in the backdown areas of nets reduces porpoise entanglement, and increases the probability of an effective release. The tie-down points on the net for preparing the backdown channel must be properly located in order to optimize porpoise release. A formula uses the stretched depth of the net to calculate one of these points, making it a simple matter to locate the other. Understanding the dynamics of the backdown procedure permits a thorough troubleshooting of performance, thus preventing the repetition of poorly executed backdowns and thereby reducing mortality.

Porpoise that cannot be released must be rescued by hand. A rescuer in a rigidly inflated raft can rescue porpoise effectively at any time during a net set. Hand rescue can make the difference between above average kill and zero kill sets. In all circumstances, the skill and motivation of the captain and his crew are the final determinants in the prevention of incidental porpoise mortality in tuna seining.

The Scombrids of the World

The Scombridae comprise 15 genera and 49 species of mostly epipelagic marine fishes—mackerels, Spanish mackerels, bonitos, and tunas—which support very important commercial, recreational, and artisanal fisheries throughout the world's tropical and temperate waters. The family is divided into two subfamilies, the Gasterochismatinae (with only one species, *Gasterochisma melampus*) and the Scombrinae. The latter is divided by internal osteological characters into two groups of tribes: The more primitive mackerels (Scombrini) and Spanish mackerels (Scomberomorini), and the bonitos (Sardini) and the higher tribe Thunnini.

Authors Bruce B. Collette and Cornelia E. Nauen have prepared the FAO's second worldwide species catalog, issued within the FAO Fisheries Synopsis series as FIR/S125 Vol. 2, **"Scombrids of the World,"** subtitled "An Annotated and Illustrated Catalogue of Tunas, Mackerels, Bonitos, and Related Species to Date." The volume has an illustrated glossary of technical terms and measurements and the "Systematic Catalogue" presents an excellent illustrated key to the genera and species of the Scombridae. Species information includes data on scientific names and local names as well as FAO names in English, French, and Spanish. Diagnostic features are reported and illustrated as needed, geographic distribution is reported and mapped for each species, size data is given, as well as fisheries and utilization data, and pertinent literature citations. Extensive information on each species' habitat and biology is also given.

The volume is very well written and illustrated and will be of great interest and use to biologists, researchers, and administrators involved with scombrids and their fisheries. The 137-page paperbound volume is indexed by scientific and international FAO names and local names and contains an extensive bibliography. Species are also listed by major FAO statistical fishing area. The volume is available from Unipub, 205 East 42nd St., New York, NY 10017 (price not listed).

AAAS Symposium on Aquatic Ecosystems

"Trophic Interactions Within Aquatic Ecosystems," edited by Dewey G. Meyers and J. Rudi Strickler, has been published by the Westview Press, 5500 Central Avenue, Boulder, CO 80301, as AAAS Selected Symposium 85. The volume is based on a symposium held at the 1981 AAAS National Annual Meeting, 3-8 January 1981 in Toronto, Ontario, Canada, and cosponsored by AAAS Section G (Biology).

Briefly, 21 prominent ecologists examine aquatic food chain interactions in light of the structure and functioning of aquatic ecosystems. In 14 papers, they review relevant background literature, present their experimental findings, and predict significant areas of future research. The papers are presented in four parts: Phytoplankton (resource supply rates and phytoplankton community structure; ecological implications of patchiness in nutrient supply, and the impact of grazing and nutrient release on phytoplankton community structure). Zooplankton papers discuss calanoid copepod grazing on small and large particles, rotifer grazing rates and selectivity, copepod feeding mechanisms, cladoceran lipid reserves, and copepod feeding and evolution. In Part 3, "Fish," is a moden analysis of the feeding ecology of the white crappie and an analysis of contemporary models of foraging efficiency, resource partitioning, competition, and evolutionary divergence. The final section, "Community," provides a variety of views of food web dynamics in lake ecosystems. Indexed, the 472-page hardbound volume is available from the publisher for $35.00.

The Toxins Found in Marine Foods

"Seafood Toxins," edited by Edward P. Ragelis of the U.S. FDA, has been published as ACS Symposium Series 262 by the American Chemical Society, 1155 Sixteenth Street, N.W., Washington, DC 20036. The volume is based on a symposium sponsored by the Division of Agricultural and Food Chemistry of the American Chemical Society at the ACS 186th Meeting, 28 August-2 September 1983 in Washingon, D.C. The volume is an excellent and up-to-date compilation of data and reviews on an important topic, since toxins can be a major impediment to the development of many millions of dollars worth of latent high-quality fishery resources and can adversely affect literally tens of thousands of people worldwide.

Important toxins covered in the volume's 37 chapters include: Paralytic shellfish poison (PSP); tetrodotoxin (pufferfish) TTX; ciguatera, scombroid-related, and *Ptychodicus brevis* toxins; diarrhetic shellfish poison; and neurotoxins, endotoxins, and peptide toxins associated with blooms of certain strains of blue-green algae (cyanobacteria). Along with their reviews and studies, the authors also identify and recommend future epidemiological, toxicological, and chemical research needs. Some chapters present new and previously unpublished data; others are a synthesis of existing information.

The volume is divided into six sections, the first an overview presenting excellent reviews of U.S. marine resource development, especially as it may be affected by marine toxins, paralytic shellfish poisoning, ciguatera poisoning, and a wide variety of miscellaneous seafood toxicants. Alaska's shellfish industry, and risks and benefits of seafood, are also discussed.

The second section on shellfish toxins, presents 12 papers on such issues as diarrhetic shellfish poisoning, paralytic shellfish toxins and finfish toxins in tropical waters, biosynthesis of paralytic shellfish toxins, cryptic paralytic shellfish toxins, a historical perspective on paralytic shellfish poison, taxonomic and biogeographic aspects of toxic dinoflagellates, and more. Another eight papers then deal with ciguatera toxins, two with tetrodotoxin, five with toxins from red tide and cyanobacteria, and three with aspects of scombroid fish poisoning.

The volume thus consolidates the work of many recognized authorities in the field of seafood toxins, their chemistry, origins, and geographic distribution, pharmacological aspects, monitoring and detection methods, etc. Authoritiative and well written, the papers will be of considerable interest and use to scientists, pharmacologists, and others involved in seafood research and regulation. The 460-page hardbound volume is indexed by subject and author, and is available from the publisher for $79.95 (U.S. and Canada) and $95.95 elsewhere.

Ancient and Modern Fish Harvest Methods

The third and greatly expanded edition of **"Fish Catching Methods of the World,"** by Andres von Brandt, has been published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. It is almost double the size of the original 1964 edition, and the author discusses how fishes can be caught, in the broadest sense. Its 31 chapters review and thoroughly illustrate fish catching methods from stone age techniques to the most modern gear and techniques, although much of it is devoted to an extensive review of essentially small-scale or artisanal fishing methods.

Following a brief introductory chapter, the author relates means of hand gathering fishes; diving techniques of men and women; using various animals such as horses, birds, porpoise, etc. to harvest fish; stupefying fish; fishing with spear, harpoon, arrow, etc.; and the use of clamps, tongs, rakes, and wrenching gear. The author also reviews basic line fishing implements; gear and methods of line fishing; sport fishing gear; fish attraction methods including lures, lights, chemicals, etc.; gaffs, fish harrows, and jigs; natural and artificial shelters; mechanical traps and snares; fish trapping with permanent and temporary barriers, traps, pots, etc.; and catching jumping fish.

Several chapters deal with a wide variety of nets and netting: Scoop nets, trawls and trawling, seines and seining, surround nets, lift nets, cast nets, gillnets, entangling nets, making nets, and much more. Another chapter discusses fishing rituals and religious beliefs and another is presented on fishing systems and harvesting machines. An appendix classifies the various types of fish catching methods, and the bibliography lists 690 literature citations.

Well illustrated with 733 drawings and photographs, the 418-page hardbound volume is an extensive and thorough review of global fish harvest methods, and is available from the publisher for £27.50.

"The Complete Book of Seafood Fishing" by Rob Avery has been published by the Van Nostrand Reinhold Company, Inc., 135 West 50th Street, New York, NY 10020. The author, a British freelance writer, has provided a very basic, but fairly thorough description of ways to harvest marine fish and shellfish and preserve them. Though there is some material on commercial fishing for a living, the book is more suited to coastal residents or anglers who want to harvest marine species for food or sport.

Thus the author provides basic data on tides, where and how to find fish and shellfish, fish traps and trapping, angling from shore, nets and netting, fishing from small boats, basic seamanship, safety precautions, basic and more advanced small-boat fishing, making and mending nets, knots, safety precautions, processing and preparing the catch, making fish meal, seaweeds and their uses, and fish oils and other byproducts. In-

dexed, the 162-page hardbound volume is available from the publisher for $16.95.

The Ecology of an Estuarine Ecosystem

"Ecology of Barnegat Bay, N.J.," edited by Michael J. Kennish and Ricahrd A. Lutz, has been published by Springer-Verlag, 175 Fifth Avenue, New York, NY 10010. Kennish is with the Oyster Creek Nuclear Generating Station, Forked River, N.J., and Lutz is with Rutgers University, New Brunswick, N.J.

This monograph consists of 14 chapters by 20 scientists from academia, industry, and government who have conducted much of the Bay's ecological research in the last 20 years, largely in regard to the siting and effects of the Oyster Creek Nuclear Generating Station on Barnegat Bay, a shallow (1-6 m), lagoon-type New Jersey estuary. Many reports, published and unpublished, have been written, and this volume, in short, defines the ecological characteristics of the Bay, and provides an ecological data base for future comparison studies and impact assessments, and will be of interest to other estuarine scientists working on problems of environmental monitoring, trophic studies, and fisheries.

Chapter 1 discusses the Bay's hydrodynamics, geomorphology, and water quality, while Chapter 2 details nutrient conditions of Barnegat Bay and other New Jersey coastal bays. The estuary's phytoplankton community and its seasonal periodicities are examined in Chapter 3, while Chapter 4 describes the macroflora of the Bay. Chapter 5 provides a look of the Bay's zooplankton community, Chapter 6 reviews the benthic fauna of the Bay, and Chapter 7 describes the shellfish populations of the Bay, and reviews life history studies of the hard clam and blue crab. Chapter 8 reviews shipworms and their ecology, while Chapter 9 summarizes the fouling organisms of the Bay. Chapter 10 defines the community structure, seasonal patterns, reproductive characteristics, and population trends of bay fishes, while Chapter 11 reviews the commercial and sport fisheries of Barnegat Bay. Chapter 12 examines the complex interrelationships of the Bay's food web, and the effects of dredging, waste disposal, and operation of the nuclear plant on the bay's ecosystem are discussed in Chapter 13.

Finally, Chapter 14 reviews and summarizes the data in the first 13 chapters. Extensive references are given with each chapter, while Appendix A presents a bibliography of unpublished papers, theses, and government reports on the Bay, many of which are not widely distributed, but which are on file in the library of the GPU Nuclear Corporation. The 396-page paperbound volume is indexed by scientific name, author, and subject, and is available from the publisher for $34.00.

Mechanically-Separated Fish Flesh Resources

The second and expanded edition of **"An Annotated Bibliography on Mechanically-Separated Finfish and Crustacea Meats,"** compiled by Frank B. Thomas, Joyce A. Taylor, and Freda A. Ramey, has been published as UNC Sea Grant Publication 84-02 by the University of North Carolina Sea Grant College, P.O. Drawer 1137, Morehead City, NC 28557, in cooperation with the Alaska Fisheries Development Foundation, Inc.

There have been many new developments since the first edition was published in 1977, and surimi products are being commercially produced on several continents. Thus, the compilers made an extensive review of the literature (with particular emphasis on established publications, trade journals, and selected technological conferences) and their annotated bibliography is a ready source of information for scientists, students, and others interested in this aspect of fisheries utilization. Reference to patents are also included, and the publication is a handy guide to the recent literature and summary of the state of the art. It includes 135 pages of annotated citations, 4 pages of patents, a subject index by category (i.e., raw materials and resources, applications, nutritive value, etc.). It also lists several selected reference books and proceedings, meetings and symposiums, and abstracts and indexes. The 170-page paperbound volume is available from the publisher for $4.00.

Packaging and Shipping Fish and Seafood Products

The **"Proceedings of the First National Conference on Seafood Packaging and Shipping,"** edited by Roy E. Martin, Vice President, Science and Technology, National Fisheries Institute, 2000 M Street, N.W., Suite 580, Washington, DC 20036, has been published by the Institute. The conference, held 15-17 November and 7-9 December 1982 in Washington, D.C., and Seattle, Wash., respectively, was jointly sponsored by the NFI, the National Marine Fisheries Service, and the Universities of Alaska and Washington.

In sum, the volume is an excellent review of current research and development activities and recent technological advances in packaging, shipping, and extending the quality of seafoods. Conference sessions were devoted to modern and future transportation methods, packaging, handling, and shipping of seafoods, shipping containers, air transportation, controlled and modified atmosphere packaging, new techniques for fish distribution and regulatory concerns. In the final section, NFI has reprinted a series of pertinent technical articles and guidelines on use of modified atmospheres, vacuum packaging, airline shipping requirements/procedures or policies, containers for seafoods, and more. The 599-page paperbound volume is available from the NFI (no price listed).

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Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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